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EVALUATION OF WEAPONS' COMBUSTION PRODUCTS IN ARMORED VEHICLES

Final Report

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The U.S. Army Biomedical Research and Development Laboratory defined an extensive research program to address the generation of potentially toxic propellant combustion products in crew compartments of armored vehicles during weapons firing. The major objectives of the research were (1) to determine the presence and concentration of propellant combustion products, (2) to determine potential crew exposure to these combustion products, and (3) to assess the efficacy of field monitoring in armored vehicles. To achieve these goals, air monitoring was conducted in selected armored vehicle types, i.e., M109, M60, M3, M1, at several Army installations. Auxiliary information concerning the specific munitions fired and the Training and Doctrine Command (TRADOC) or Forces Command (FORSCOM) firing scenarios was collected so that a comparison of pollutant concentrations generated by specific weapons both within vehicle types and between vehicle types could be made.

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19. **ABSTRACT (continued)**

The characterization of the airborne combustion products in armored vehicles during weapons firing exercises was facilitated by the use of optimized sampling and analysis methods to permit the collection of large sample volumes and thus enhance the ability to identify and quantify trace pollutants. Inorganic gases and members of several compound classes were found in one or more armored vehicles during firing:

WEAPON POLLUTANTS

Carbon Monoxide	Vapor Phase Organics
Ammonia	Aldehydes
Carbon Dioxide	Polycyclic Aromatic Hydrocarbons (PAHs)
Hydrogen Cyanide	Nitro-PAHs
Hydrogen Sulfide	Particulates (Total, Respirable)
Nitrogen Oxides	Metals
Sulfur Dioxide	

On several occasions, carbon monoxide concentrations in tanks averaged over 400 ppm for 15-minute periods. On one occasion (loader/breathing zone, Fort Knox M1 tank), the carbon monoxide monitor reading exceeded 1500 ppm for almost 40 minutes continuous duration; the NRC recommended Emergency and Continuous Exposure Limit is 1500 ppm for 10 minutes. Other monitors in the same vehicle, however, were consistently below the NRC Limit. Carbon monoxide was observed to exceed 2000 ppm for shorter periods in all vehicle types except the M3, where the peak level was 1300 ppm. Mean carbon monoxide concentrations ranged from 3.6 to 4.7 ppm in the non-tank vehicles (M3 and M109) and from 35 to 43 ppm in the tanks. With few exceptions, the maximum concentrations of all other pollutants in all vehicles were less than their respective threshold limit values and short-term emergency exposure levels.

The peak instantaneous concentrations of pollutants generated during weapon firing, and to which crewmen such as the ammunition loader are exposed, may exceed 500 times the average concentrations inside vehicles. These peak excursions are very localized and short-lived. Carbon monoxide, which is a major combustion product, is observed at statistically significantly higher mean and peak concentrations in tanks (M1; M60) compared to non-tank vehicles (M3; M109). All other pollutants are generally observed at higher levels in tanks than non-tank vehicles, although the statistical significance of this observation is affected by sample size and variability.

The rigor and complexity of field sampling in armored vehicles during firing exercises can be successfully dealt with if proper planning and careful limitation of the duration of sampling is followed. The use of sampling vests for breathing zone measurements is feasible although subject to failure due to the activity of the subject.

FOREWORD

Opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed by the U.S. Army.

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ABSTRACT

The U.S. Army Biomedical Research and Development Laboratory defined an extensive research program to address the generation of potentially toxic propellant combustion products in crew compartments of armored vehicles during weapons firing. The major objectives of the research were (1) to determine the presence and concentration of propellant combustion products, (2) to determine potential crew exposure to these combustion products, and (3) to assess the efficacy of field monitoring in armored vehicles. To achieve these goals, air monitoring was conducted in selected armored vehicle types, i.e., M109, M60, M3, M1, at several Army installations. Auxiliary information concerning the specific munitions fired and the Training and Doctrine Command (TRADOC) or Forces Command (FORSCOM) firing scenarios was collected so that a comparison of pollutant concentrations generated by specific weapons both within vehicle types and between vehicle types could be made.

The characterization of the airborne combustion products in armored vehicles during weapons firing exercises was facilitated by the use of optimized sampling and analysis methods to permit the collection of large sample volumes and thus enhance the ability to identify and quantify trace pollutants. Inorganic gases and members of several compound classes were found in one or more armored vehicles during firing:

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The peak instantaneous concentrations of pollutants generated during weapon firing, and to which crewmen such as the ammunition loader are exposed, may exceed 500 times the average concentrations inside vehicles. These peak excursions are very localized and short-lived. Carbon monoxide, which is a major combustion product, is observed at statistically significantly higher mean and peak concentrations in tanks (M1; M60) compared to non-tank vehicles (M3; M109). All other pollutants are generally observed at higher levels in tanks than non-tank vehicles, although the statistical significance of this observation is affected by sample size and variability.

The rigor and complexity of field sampling in armored vehicles during firing exercises can be successfully dealt with if proper planning and careful limitation of the duration of sampling is followed. The use of sampling vests for breathing zone measurements is feasible although subject to failure due to the activity of the subject.

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The successful accomplishment of this study was facilitated by the extraordinary efforts of both a dedicated field team and diligent representatives of the U.S. Army field commands.

Field personnel including J. Adams, R. Almeida, S. Locke, and C. Willis spent many hours before dawn preparing equipment for sampling and many hours unobtrusively rocking to the noise and motion of armored vehicles during fighting.

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The authors wish to express their gratitude to each of these individuals without whom the program would have been "bumpier" than it was.

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TABLE OF CONTENTS

CONTENTS (continued)

CONTENTS (continued)

LIST OF FIGURES

FIGURES (continued)

LIST OF TABLES

TABLES (continued)

TABLES (continued)

ABBREVIATIONS AND SYMBOLS

°F	Degrees Fahrenheit
ppm	Parts per million (v/v)
ppb	Parts per billion (v/v)
μg	Microgram (10^{-6} g), unit of mass
m^3	Cubic meter, unit of volume
$\mu g/m^3$	Micrograms per cubic meter, unit of concentration
mm	Millimeter, unit of length
Hr	Hour
min	Minute
TRADOC	Training and Doctrine Command
FORSCOM	Forces Command
PAH	Polycyclic aromatic hydrocarbons
CO	Carbon monoxide
CO_2	Carbon dioxide
NO	Nitric oxide
NO_2	Nitrogen dioxide
HCl	Hydrogen chloride
HCN	Hydrogen cyanide
NH_3	Ammonia
H_2S	Hydrogen sulfide
M109	Self-propelled Howitzer
M60	Main battle tank
M1	Abrams tank
M3	Bradley Fighting Vehicle
GA	General area
BZ	Breathing zone
TOTCONC	Analyte concentration during exercise
FIRECONC	Analyte concentration during active firing
GC	Gas chromatography
MS	Mass spectrometry

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1.0 INTRODUCTION

The U.S. Army Medical Biomedical Research and Development Laboratory defined an extensive research program to address the generation of potentially toxic propellant combustion products inside the crew compartments of armored vehicles during weapons firing exercises. The major objectives of the research were (1) to determine the presence and concentration of propellant combustion products, (2) to determine potential crew exposure to these combustion products, and (3) to assess the efficacy of field monitoring in armored vehicles. To achieve these goals, air monitoring was conducted in selected armored vehicle types, i.e., M109, M60, M3, M1, at several Army installations. Auxiliary information concerning the specific munitions fired, i.e., 155 mm, 105 mm, 25 mm, 7.62 mm and 50 CAL shells, and the Training and Doctrine Command (TRADOC) or Forces Command (FORSCOM) firing scenarios was collected so that a comparison of pollutant concentrations generated by specific weapons both within vehicle types and between vehicle types could be made.

The basic approach to this experimental program was twofold. First, optimized industrial hygiene monitoring techniques were used to qualitatively and quantitatively determine the chemical composition of the air inside armored vehicles during weapon firing. Second, a statistical comparison of pollutant concentrations was undertaken to permit an assessment of potential exposure of crew members to both organic and inorganic chemical compounds. The first task required the use of portable/rugged sampling equipment for the field collection of as large an air sample as practical and the analysis of the sample by the most sensitive and accurate method feasible. The second task required the comparison of general area samples and breathing zone samples across vehicle types and also at selected functional positions within a vehicle type.

1.1 BACKGROUND

1.1.1 Weapons' Combustion Products

Several studies have characterized the weapons' combustion products generated either by laboratory combustion or by field firing in armored vehicles.[1-3] Even though the characterizations were not complete, they indicated that the combustion products contain in excess of 100 chemical species that include stable gases as well as volatile organics, semi-volatile organics, and metals in particulate and vapor phases. Many of the chemicals detected, e.g., carbon monoxide and benzene, are known to be capable of causing significant toxic effects in humans. Other chemical species, not detected in the earlier studies because of limitations in sampling and analytical methodologies, may also be present and have major potential effects; these could include polynuclear aromatic hydrocarbons (PAHs) and nitro-PAHs (NO_2-PAH). As methods to characterize and identify combustion product constituents from military weapons are improved, the impact of these products on the performance and health of the soldier may be evaluated. A review of the current toxicology

literature will provide some relevant information; however, until personal exposure can be determined, the significance of the problem cannot be understood with any degree of certainty. Sampling air from the breathing zones of soldiers during weapon firing exercises is one method of measuring personal exposure through the inhalation route.

Therefore, in order to support the U.S. Army's Health Hazard Assessment Program (Army Regulation 40-10, Health Hazard Assessment Program in Support of the Army Materiel Acquisition Decision Process), additional information on the potential health hazards from gun combustion products was sought. A complex suite of products of incomplete combustion may be generated as a result of weapon firing.[1] However, the chemical inventory of these products is not well defined from a quantitative point of view, nor is it qualitatively complete. These products result from the combustion/pyrolysis of propellants and igniters used in ammunition. The major functions and components of the propellant and igniter used in 105-mm shells, for example, are as follows:

TABLE 1. PROPELLANT COMPOSITION[2]

Function	Component(s)
Fuel/oxidizable material	Nitrocellulose Low-grade nitrocellulose (nitrogen in nitrocellulose) Nitroglycerine Nitroguanidine
Stabilizer	Ethyl centraline (diethyl diphenyl urea)
Anti-flash agent	Cryolite (sodium aluminum fluoride)
	Igniter
Fuel/oxidizable material	Nitrocellulose
Oxidizer	Black powder (carbon, sulfur, sodium nitrate)

The combustible materials in the propellant react with oxygen bound within their chemical structure rather than with oxygen from the air. The stoichiometry of the self-oxidation reactions is determined by the oxygen balance of the fuel/oxidizable materials which may be either positive or negative. In most cases, propellants are fuel rich and complete oxidation to carbon dioxide and water is not readily achieved. Thus, it is not surprising that carbon monoxide, hydrogen, and carbon

dioxide are all major pyrolysis/combustion products.[2] Combustion gases from a 105-mm caliber gun contain about 10% by volume of each.

Many other incompletely oxidized forms of propellant components have been reported, although at low concentrations.[1] Incomplete combustion due to fuel-rich conditions and quenching of free-radical reactions leads to partial oxidation of organic constituents, resulting in the formation of alcohols, aldehydes, ketones, and acids and substituted species containing nitrogen and sulfur. These latter substituted species include organo-cyanides, amines, and thiocyanates. The presence of a large number of organic classes highlights the difficulty in identifying and quantifying the combustion products.

A number of potentially toxic inorganic compounds have been observed; including ammonia, hydrogen cyanide, and hydrogen sulfide. Low levels of particulate metals have been observed in combustion products and attributed to the presence of metals in propellants, igniters, primers, and, of course, shell casings. Metals such as antimony, arsenic, barium, copper, lead, and zinc have been noted. A significant fraction (at least 25%) of the total particulate generated during firing may exist in the inhalable size fraction (<10 μm).

This brief review of the available literature on weapon combustion products indicates that several key unanswered questions remain with respect to an assessment of the health hazard associated with the combustion products in armored vehicles.

What remains unknown is:

(1) The extent of exposure of vehicle crew members to major combustion products, especially carbon monoxide;

(2) The completeness of the inventory of trace combustion products due to limitations in analytical techniques; and

(3) The extent of exposure of vehicle crew members to such trace organic and inorganic compounds.

Of the major combustion products, based on the concentrations identified in the literature,[1] carbon monoxide is of most concern toxicologically since its threshold limit value is far lower than for carbon dioxide or hydrogen. Most of the trace combustion products are likely to be present at levels 10^{-3} to 10^{-7} times lower than the concentration of carbon monoxide. Of course, many of these pollutants are quite toxic (some carcinogenic) and may still pose a health hazard. The inventory of potentially hazardous trace pollutants cited in the current literature often fails to include the one- and two-carbon members of many organic compound classes since they are not collected efficiently by typical sorbents such as Tenax®. Formaldehyde, for example, should be collected on a coated sorbent tube, e.g., DNPH on Florisil®, to provide appropriate capacity and recovery.

1.1.2 Monitoring Techniques

Sampling and analysis techniques suitable for this field program required portable, internally powered, rugged and accurate instrumentation. Industrial hygiene (IH) sampling techniques include methods that trap air contaminants in liquid media, on adsorbent solids, or on particulate filters. Direct reading techniques are also employed. Many of these techniques have been standardized as the National Institute of Occupational Safety and Health (NIOSH) methods,[4,5] and therefore, have been evaluated for accuracy, precision, and reliability. Reviews of conventional IH sampling techniques[6,7] discuss midget impingers and bubblers, sorbent tubes, passive diffusion monitors, direct reading instruments, and particulate samplers. Impingers and bubblers are filled with a liquid medium that traps gaseous and particulate contaminants when air is drawn through the liquid by an air pump. Since this method requires individuals to limit their activities to prevent spillage of the sampling medium,[6,8] it was of limited usefulness for this project because of the intense physical activity in military field training exercises.

A variety of solid sorbents, packed into small cartridges, have been found to be useful for sampling gases, vapors, mists, fumes, and aerosols. As with the impingers, contaminated air is drawn through the sorbent-filled cartridge by an air sampling pump. The sorbent type determines the contaminants that can be sampled, and it may be specific for a single chemical or for a class of chemicals. Commonly used sorbents include charcoal, silica gel, activated alumina, Porapak Q, Tenax-GC, XAD, and reagent-coated solids that react chemically with the contaminant.[6,7] Some of the sorbents are chromosorbs that have colorimetric reactions proportional to the contaminants' concentrations, thus providing immediate results without laboratory analysis. Passive diffusion monitors also use solid sorbents; however, the need for an air sampling pump is eliminated.[6,7] Sampling in passive monitors is dependent upon mass transport across a diffusion layer or permeation through a membrane.[7] Direct reading instruments have sensors that react with a specific air contaminant, e.g., carbon monoxide, and produce an electrical signal proportional to the contaminant's concentration. This type of instrument can provide real-time measurements.

Reviewing IH sampling techniques, Ramsey, et al.,[7] discussed how particulates could be collected with a sampling pump attached to an impinger, filter, or impactor. Impingers and their limitations were discussed earlier. Filters of different sizes, porosity, and material are used to collect total particulates that can be analyzed gravimetrically, microscopically (e.g., fiber counting), or chemically for metals or adsorbed substances. Cyclones and elutriators can be used to collect respirable particulates, and size fractionation can be accomplished with cascade impactors.

In addition to conventional IH sampling techniques, other methods have been developed and reported in the scientific literature. One method involved the use of an evacuated container equipped with a valved

critical orifice for air sampling.[6,9] As long as the pressure in the container is less than 380 torr (1/2 atm), a 3 μm orifice allows constant flow sampling for eight hours. This system has been used to collect carbon monoxide (CO), benzene, toluene, xylene, hexane, pentane, and trichloroethylene. Chemically impregnated paper tapes have been investigated and reported to successfully monitor aromatic amines,[10] β-propiolactone and other alkylating agents,[11] phosgene, toluene diisocyanate, chlorine, sulfur dioxide, nitrogen dioxide, hydrogen sulfide and vinyl chloride.[12] Passive dosimetry technology has been used with novel analytical approaches, such as direct detection by room temperature phosphorescence (RTP) to monitor PAH vapors,[13] and total elemental content analysis to measure chlorine.[14] A NIOSH sponsored study in the late 1970s concluded that it might be feasible to develop a pocket-sized gas chromatograph (GC) active personal monitor.[6] The concept has been used to produce a miniature GC column on a 2-inch silicon wafer using microetching technology. This instrument can selectively monitor ten different contaminants, provide real-time warning of acute exposures, and also provide an 8-hour time-weighted-average (TWA) of a worker's exposure to each contaminant.

Breathing zone sampling is a method commonly used to measure personal exposure to air contaminants, primarily for occupational exposures.[4-7,15-17] The U.S. Environmental Protection Agency (USEPA) is expanding the technique for monitoring total exposure of a nonoccupational nature.[18-20] Ideal sampling devices for personal monitoring must sample accurately, not interfere with routine activities, be conveniently activated and deactivated, and be small, lightweight, and nonrestrictive.[6,15] Gold, et al.,[15] developed a sampling system that met these criteria. The system was incorporated into the turnout coat of firefighters, and it successfully sampled CO, CO_2, NO_2, HCl, HCN, and particulates during firefighting operations.

1.2 SCOPE OF WORK

The scope of work defined for this program can be summarized in terms of three general tasks.

These included:

(1) Characterization of weapon combustion products;

(2) Exposure evaluation (field sampling and analysis); and

(3) Statistical analysis.

These tasks provided data with which to satisfy the objectives of the program:

a. Determine identity and concentration of propellant combustion products in selected armored vehicles;

b. Determine the potential crew exposure to these combustion products; and

c. Assess the efficacy of field sampling of propellant combustion products.

In order to characterize the weapon combustion products, both optimized IH techniques and state-of-the-art sampling and analysis techniques were utilized. General area samples collected during initial sampling trips were analyzed to develop an inventory of potentially toxic pollutants in armored vehicles. Appropriate techniques were used so as to ensure that key compound classes were evaluated:

- PAH and PAH derivatives, e.g., nitro-PAH;
- Organic vapors;
- Metals;
- Aldehydes;
- Inorganic gases; and
- Particulates and particle size distribution.

In order to provide quantitative data on the concentration of weapon combustion products within the vehicles, an extensive field effort was conducted. This effort involved general area sampling and breathing zone sampling within four types of vehicles at TRADOC facilities and FORSCOM facilities.

Subtasks within this field effort included the following work:

SUBTASK 1: (a) Preparation of sampling equipment

(b) Preliminary site visits

(c) Preparation of sampling and analysis plan

SUBTASK 2: (a) Initial sampling trip and evaluation of techniques

(b) Modifications of procedures as necessary

SUBTASK 3: (a) General area and breathing zone sampling at four installations

(b) Collection of three general area and three or four breathing zone samples within each of four or five vehicles of four types for two days at a specific installation

(c) Chemical analysis of samples

SUBTASK 4: Statistical evaluation of data so as to test hypotheses of agreement among data within and across vehicle types and commands

In Subtask 4, there are three data objectives for assessment of personal exposures in armored vehicles. The first is to measure and compare pollutant concentrations across selected armored vehicles. Secondly, pollutant concentrations determined on the basis of general area (GA) sampling and personal breathing zone (BZ) sampling are to be compared. The third objective is to compare exposures of selected crew positions within weapon systems.

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2.0 METHODOLOGY

2.1 RATIONALE FOR STUDY

2.1.1 Objectives

The U.S. Army Biomedical Research and Development Laboratory and U.S. Army Environmental Hygiene Agency have characterized combustion products from military propellants. These programs have led to the generation of an inventory of pollutants and a tentative ranking of the significance of individual compounds in terms of health hazard. Such information is critical to a comprehensive assessment of health hazard as it relates to the Army Materiel Acquisition Decision Process.

However, as noted in the Introduction, two key issues concerning potential hazard remain unresolved and thus limit the Army's ability to address specific questions relating to crew members' exposure in armored vehicles. The first issue relates to the uncertainty of the specific weapon combustion products present in armored vehicles. The second issue relates to a lack of knowledge about the actual exposure of crew members to these pollutants. In order to resolve these issues, optimized standard sampling and analysis techniques as well as some state-of-the-art techniques were used to increase the current inventory of weapon combustion products. Utilizing the techniques, an experimental program was designed to permit comparison of potential exposure levels in armored vehicles for individual functional crew categories.

2.1.2 State-of-the-Art Characterization of Weapons' Combustion Products

Integral to the conduct of this study was the identification of weapons' combustion products which are released into the interior of armored vehicles during training and battle scenarios. The Army has conducted a limited number of studies to characterize these pollutants. The few studies are also limited with respect to the range of analytical methodologies used for pollutant identification. However, on the basis of these previous GC/MS analyses of organic vapors and directed analyses of inorganic gases, specific compounds and classes of compounds should be monitored to enhance both qualitative and quantitative information (Table 2).

TABLE 2. WEAPON POLLUTANTS/COMPOUND CLASSES

Carbon Monoxide	Vapor Phase Organics
Ammonia	Aldehydes
Carbon Dioxide	Polycyclic Aromatic Hydrocarbons (PAHs)
Hydrogen Cyanide	Nitro-PAH
Hydrogen Sulfide	Particulates (Total, Respirable)
Nitrogen Oxides	Metals
Sulfur Dioxide	

To facilitate these analyses, the following classes of compounds were selected for monitoring with optimized "standard" sampling and analysis techniques:

TABLE 3. OPTIMIZED "STANDARD" TECHNIQUES

Compound	Sampling	Analysis
PAH	Filter/sorbent	HPLC/UV/Fluorescence
Organic vapors (>100°C BP)	Tenax®	GC/MS
Metals	Filter	ICAP
Inorganic gases (CO, CO_2, NO_x, H_2S, SO_x, HCN)	Sorbent/reactive materials	Various
Particulates	Filter	Gravimetry

This program also addressed other pollutants including volatile organic compounds, aldehydes and nitro-PAHs which are not readily determined by standard techniques and may have been overlooked in previous studies. Therefore, recently developed analytical techniques were used for their analysis.

Specifically, a recently evaluated analytical technique for nitro-PAH in diesel exhaust[21] utilizing filter and sorbent collection followed by a very sensitive GC/electron capture detector analysis was utilized to analyze the same samples as for PAH. In the case of organic vapors, the limited collection capacity of Tenax® for low molecular weight compounds[22] was overcome with a carbonaceous sorbent, i.e., Ambersorb®, which has collection capacity greater than Tenax® and good thermal desorption ability compared to charcoal. The combination of Tenax® and Ambersorb® yielded an optimum sampling device for low molecular weight organic vapors. GC/MS was used for identification and quantification of these compounds.

Aldehydes have previously been difficult to measure as a result of poor collection due to low molecular weight or poor chromatography due to polarity. A recently evaluated dinitrophenylhydrazone (DNPH) method for aldehydes and ketones in diesel exhaust[23] was utilized for this program. A DNPH-coated sorbent tube was used for collection of all aldehydes excluding formaldehyde, and analysis was conducted by HPLC (UV).

2.1.3 Air Monitoring Design

A number of hypotheses were tested within this experimental program. These hypotheses relate to differences in the exposure among crew members to propellant combustion products released inside armored vehicles.

The Army operates a variety of armored vehicles as part of its overall tactical battle plan. Generally, these vehicles include tanks, such as the M1 Abrams Tank and M60; self-propelled Howitzers, such as the M109; and personnel carriers, such as the Bradley Fighting Vehicle (M3). Within each type of vehicle, the crew members fill different functions, e.g., driver, gunner, loader or commander, and each may occupy a discrete space within the vehicle.

The mass and composition of propellant combustion products released into a vehicle as a result of firing may vary among vehicle types as a result of differences in the number and type of weapons. The specific types of weapons (caliber) and mass of propellant fired in each vehicle are noted below:

TABLE 4. TYPE OF VEHICLE WEAPONS FIRED AND PROPELLANT MASS

	Weapon Caliber Used				
Vehicle	155 mm	105 mm	25 mm	7.62 mm	50 cal
M1		5.7 kg		0.003 kg	
M3			0.10 kg	0.003 kg	
M60		5.7 kg		0.003 kg	0.016 kg
M109	12 kg				

For example, the M109 contains a 155-mm cannon, while the Bradley Fighting Vehicle (M3) contains a 25-mm cannon. As a result of differences in weapon types and firing rate in each type of vehicle, the composition and distribution of propellant combustion products may vary.

Although all four vehicle types are designed differently, basic similarities exist with respect to crew locations and functional requirements existing within each vehicle (Figure 1). Specifically, the following general areas (GA) are common to all three types:

(1) Forward control (driver) area;
(2) Weapon (loader) area; and
(3) Command/observation (commander) area.

In each of the four vehicles, the forward control area is set well apart from the rest of the crew compartment. The weapon area and command/observation area are somewhat less distinct. In the M3, a raised turret exists which is distinct from the larger crew compartment. In the M109, a command area exists within but slightly above the weapon handling area. Each of these three areas, which are common to all

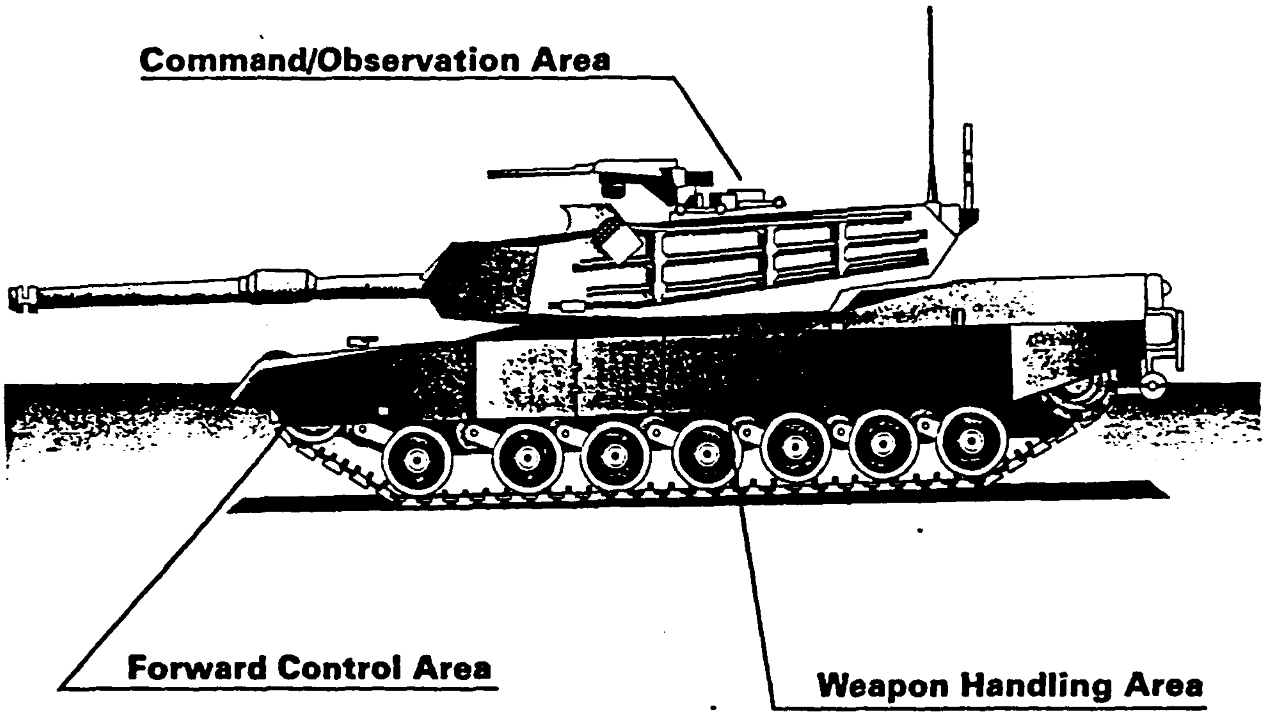

Figure 1. M1 Abrams Tank.

vehicles, may show different concentrations of propellant combustion products due to their locations with respect to the gun breech and air flow within the vehicle. These three general areas were thus monitored in each vehicle and the differences among them evaluated.

For the same reasons, it is likely that the exposure of crew members within vehicles may be significantly different. The driver will occupy the forward control area during movement but alternatively may occupy the weapon handling area during firing. Other crew members will generally move within the weapon area or command/observation area and perhaps be subjected to greater exposure. Functionally, three crew tasks are common to all vehicles, although this is somewhat less well defined in the M3. Specifically, a driver steers the vehicle and a commander directs the overall operation of the vehicle. A gunner/loader operates the cannon, e.g., 155 mm, 105 mm or 25 mm, in each vehicle. Additionally, an ammunition loader (or secondary gunner) may exist in each vehicle. The additional crew (riflemen) in the M3 fulfill functions which are not common to the M1, M60 or M109 and thus provide no useful point of comparison or hypothesis testing. Thus, three or four common crew positions were identified for breathing zone (BZ) sampling:

(1) Driver;
(2) Commander;
(3) Loader; and
(4) Gunner.

In summary, exposure to propellant combustion products is likely to depend on three factors:

(1) Vehicle type;
(2) Physical location; and/or
(3) Crew function.

However, one additional factor may influence test measurements of crew exposure to weapon pollutant; namely, the difference in field scenarios utilized by the Army. Specifically, two scenarios are of interest:

(1) Individual Skill Training; and
(2) Crew Combat Training.

The first scenario is the mandate of the U.S. Army Training and Doctrine Command (TRADOC) where new soldiers are taught how to operate a vehicle. The second scenario is the mandate of the U.S. Army Forces Command (FORSCOM) where MOS-qualified soldiers operate a vehicle under simulated battlefield situations. With the inclusion of this factor into the experimental design, four major factors were included for hypotheses testing.

2.1.4 Statistical Sampling Design

The primary consideration in designing this experiment was to define all study objectives as clearly and unambiguously as possible. In the context of statistical design of experiments, it is necessary to do this in terms of formulating specific hypotheses to be tested. In this program, it was of primary interest to detect differences in combustion products generated at different physical locations and/or at different breathing zones among different selected armored vehicle/weapon types.

On the basis of information gathered during pre-site visits, it was determined that four to six vehicles is the typical number that would be available for sampling at most locations. In some cases, the number of vehicles approached 14-24. In this study, four different vehicles of each vehicle type were sampled on each of two days at a given military installation. A fifth vehicle was occasionally sampled to provide backup samples in case of pump failure. The two different days served as replicates of the basic experimental layout. On each day, pairs of vehicles within each vehicle type were selected and equipped to monitor different pollutants (Table 5). The first two vehicles were sampled for one combination of analytes; another distinct combination of analytes was sampled in the two other vehicles. This distribution of samples was required because of the limited space available in the vehicles and in the sampling vests. Thus, four replicates of each measurement (except eight for CO) were collected in a generic sampling location on two days. For example, four forward control (driver) area samples for "organics" were collected in the M109 vehicle type at a TRADOC post. For one analyte, CO samples were collected in all four vehicles on each day, thus providing eight replicates over two days.

As shown in Table 6, measurements were taken at six or seven uniquely identified locations within each test vehicle. As discussed earlier, three locations represented general area samples, and the other three (or four) represented breathing zone samples obtained by personal dosimetry on crew members who fulfilled one or two tasks during a firing exercise. With this configuration, observations denoted as Yi(j)kl were obtained for each pollutant at each site; that is Yi(j)kl is the measured level of exposure for a given pollutant (e.g., NO_2) in vehicle type i (i=1,2,3,4) with specific vehicle number j (j=1,2,3,4) within type i, at location k (k=1,2,...,7) on day (or in replicate) l (l=1,2). Statistical techniques (SAS Institute, Inc.) including a general linear model (GLM) were used to analyze the set of observed values Yi(j)kl.

In summary, the factors considered in the experimental plan are depicted in Figure 2. These factors included (1) the command, (2) vehicle type, (3) vehicles, (4) sampling locations (breathing zone and general area) and (5) sampling days used to obtain replicates. Based on sampling four vehicle types at a TRADOC command (M109, M60, M3, M1) and two vehicle types at a FORSCOM command (M109, M60), a total of up to 150 observations per analyte were made. Due to the availability of equipment

TABLE 5. GENERIC SAMPLING SCHEME (DAY 1)*

Sample Type (# Locations)	Vehicle Number 1	2	3	4
Breathing Zone (3 or 4 soldiers)	PAH	PAH	Metals	Metals
	SO_2	SO_2	Total Particulate	Total Particulate
	Organics	Organics	Formaldehyde	Formaldehyde
	CO	CO	CO	CO
			H_2S	H_2S
			NO_2	NO_2
General Area (3 locations)	PAH	PAH	Metals	Metals
	SO_2	SO_2	Aldehydes	Aldehydes
	Organics	Organics	Total Particulate	Total Particulate
	CO_2	CO_2	Respirable Particulate	Respirable Particulate
	NH_3	NH_3	Formaldehyde	Formaldehyde
	CO	CO	CO	CO
			H_2S	H_2S
			NO_2	NO_2
			HCN	HCN

*Analyte/vehicle pairs were reversed on Day 2; i.e., PAH group in vehicles 3 and 4 and metals group in vehicles 1 and 2.

TABLE 6. SAMPLING LOCATIONS

	Vehicle Type			
	M109		M3	M60/M1
	Ft. Sill	Ft. Carson	Ft. Benning	Ft. Carson/Ft. Knox
Breathing Zone	Driver (Instructor)	Driver	Driver	Driver
	Commander	Commander	Commander	Commander
	Loader/Gunner*	Loader/Gunner*	Loader/Gunner**	Loader*
				Gunner*
General Area	Forward Control	Forward Control	Forward Control	Forward Control
	Command/ Observation	Command/ Observation	Command/ Observation	Command/ Observation
	Weapon Handling	Weapon Handling	Weapon Handling	Weapon Handling

*Crew trainees rotate positions while wearing a vest.
**One crew member.

Factor	Number of Levels
Command	2
Vehicle Type	4
Vehicles (within type)	4
Sampling Locations	7
Replicates (days)	2/4

Illustrative Diagram

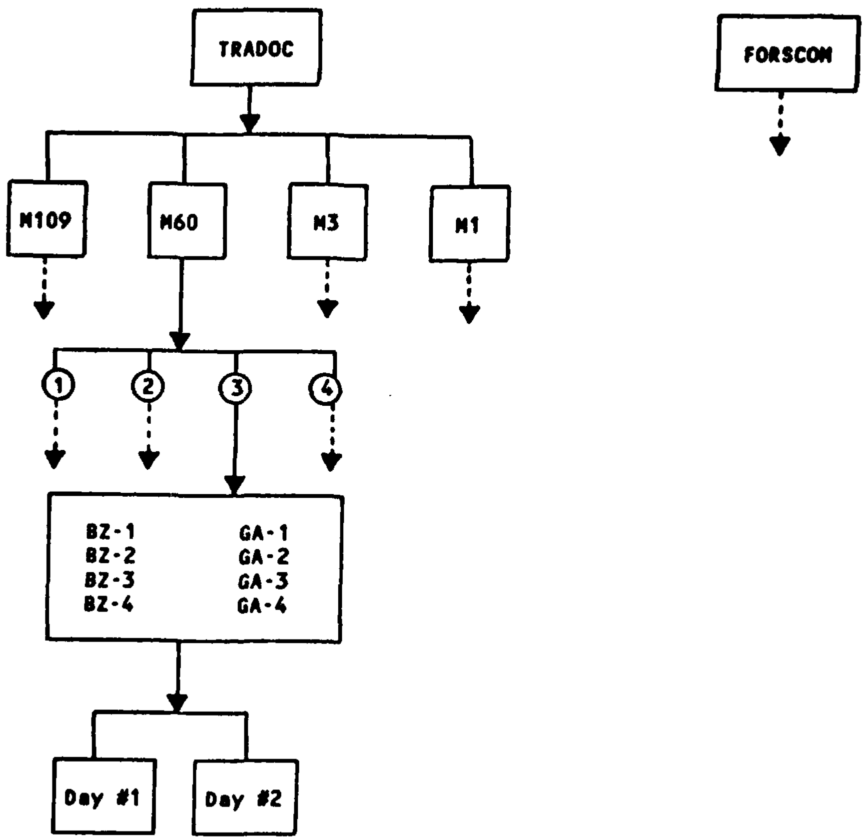

Figure 2. Schematic layout of experimental plan.

and space, CO was monitored in all four vehicles rather than two vehicles within a vehicle type at a command. In this case, about 300 CO observations were made.

Differences in concentrations between vehicles and within vehicles were determined on the basis of a general linear model of the breathing zone samples and/or general area samples.

2.2 SAMPLING STRATEGY

2.2.1 Deployment of Sampling Devices

As noted in the statistical design discussion, general area and breathing zone samples were collected in all vehicles to facilitate an interpretation of potential exposure to propellant combustion products. The three general areas described above (forward control, weapon handling, and command) were sampled in each of four vehicle types, i.e., M1, M3, M60, M109. Sampling equipment for each general area (GA) was placed in an unobtrusive location selected with agreement of the field command. Air samples were taken in each of the identified vehicles to determine the identity and concentration level of toxic components in these distinct working areas at various distances from the weapon breech or source of pollutants.

Breathing zone (BZ) samples were collected to determine the airborne concentration levels of pollutants to which the soldiers may be exposed. Each of three or four soldiers (i.e., driver, commander, gunner, loader) in the vehicle wore a sampling vest designed so as not to interfere with the person's movements. By requiring that the sampling vest be worn throughout the length of the firing exercise, a representative sample of pollutants potentially inhaled by each soldier was determined.

2.2.2 Deployment of Breathing Zone Sampling Equipment

The sampling system developed for measuring combustion product exposures of crewmen in armored vehicles was designed so as not to interfere with crewmen training activities. Gold et al.'s concept of the firefighter turnout coat[15] was combined with that of an equivalent vest worn by tank crewmen in a joint study by the U.S. Army Medical Research and Development Command (USAMRDC) and the U.S. Army Armor Center. The system is an aviation survival vest with monitors attached that will measure the environmental conditions inside a tank, e.g., heat, and physiological parameters of crewmen.

The combustion product personal sampling system thus consisted of an aviation survival vest (Vest, Survival, Large, FSN 8415-00-177-4818) modified to hold air sampling equipment (Figure 3). The sampling equipment included the pumps and instruments listed in Section 2.4, Table 8.

2.3 SAMPLING AND ANALYSIS METHODS

The sampling and analysis methods selected for air sampling were generally based on those standardized by NIOSH[4,5] and the EPA[24] or the U.S. Army Environmental Hygiene Agency (USAEHA)[3] and identified in a review of current literature. As previously noted, to characterize the weapon combustion products every attempt was made to collect a large sample and analyze this sample by the most sensitive and accurate method available. The most critical logistic limitation to deal with was the requirement to collect a sample with a battery-operated personal sampling pump since power was not available for use in the vehicles. Consistent with this requirement and the necessary rigor of the collection device, due to the shock forces found in an armored vehicle, was the use of filters and/or solid sorbent tubes for sampling. Solid sorbent tubes have a significant pressure drop which limits the practical range of flow rates available. Also, solid sorbent tubes have a limited capacity and collection efficiency. These characteristics defined the sampling parameters, i.e., flow rate and sample volume, which could be used. However, the sampling conditions (e.g., 50-200 mL/min) defined in typical industrial hygiene manuals were extended to maximize the sample volume without sample breakthrough.

The specifications of the selected methods for each analyte are listed in Table 7. The detection limit for each method is listed. Due to potentially low levels of some species in the vehicles, the sampling volume and sensitivity of the analytical method are critical parameters. Of course, positive or negative bias due to interferences or lack of sample stability are also important.

Brief descriptions of the carbon monoxide and organics methods follow and a more detailed protocol of all methods is included in Appendix A:

- CO was determined by a direct-reading ENERAC Model 60 CO monitor. The monitor has an electrochemical cell that converts CO to CO_2. The voltage produced by the oxidation process is directly proportional to the CO concentration. The voltage is read on the instrument's LCD as ppm of CO. The output of the monitor was attached to a Metrosonics d1331 data logger, set to measure a 0-1 volt range, where 1 volt DC from the CO meter indicated 2000 ppm CO.

- Organic vapors were sampled using a method developed by the U.S. Army Environmental Hygiene Agency. The sample tube used both Ambersorb® and Tenax® adsorbents thus increasing the range of organics that could be sampled beyond that of either sorbent, if used independently. Using a manifold, up to three samples were obtained at a flow rate of 0.05 LPM per sample tube. The tubes were thermally desorbed onto a capillary GC column followed by mass spectrometric (MS) analysis.

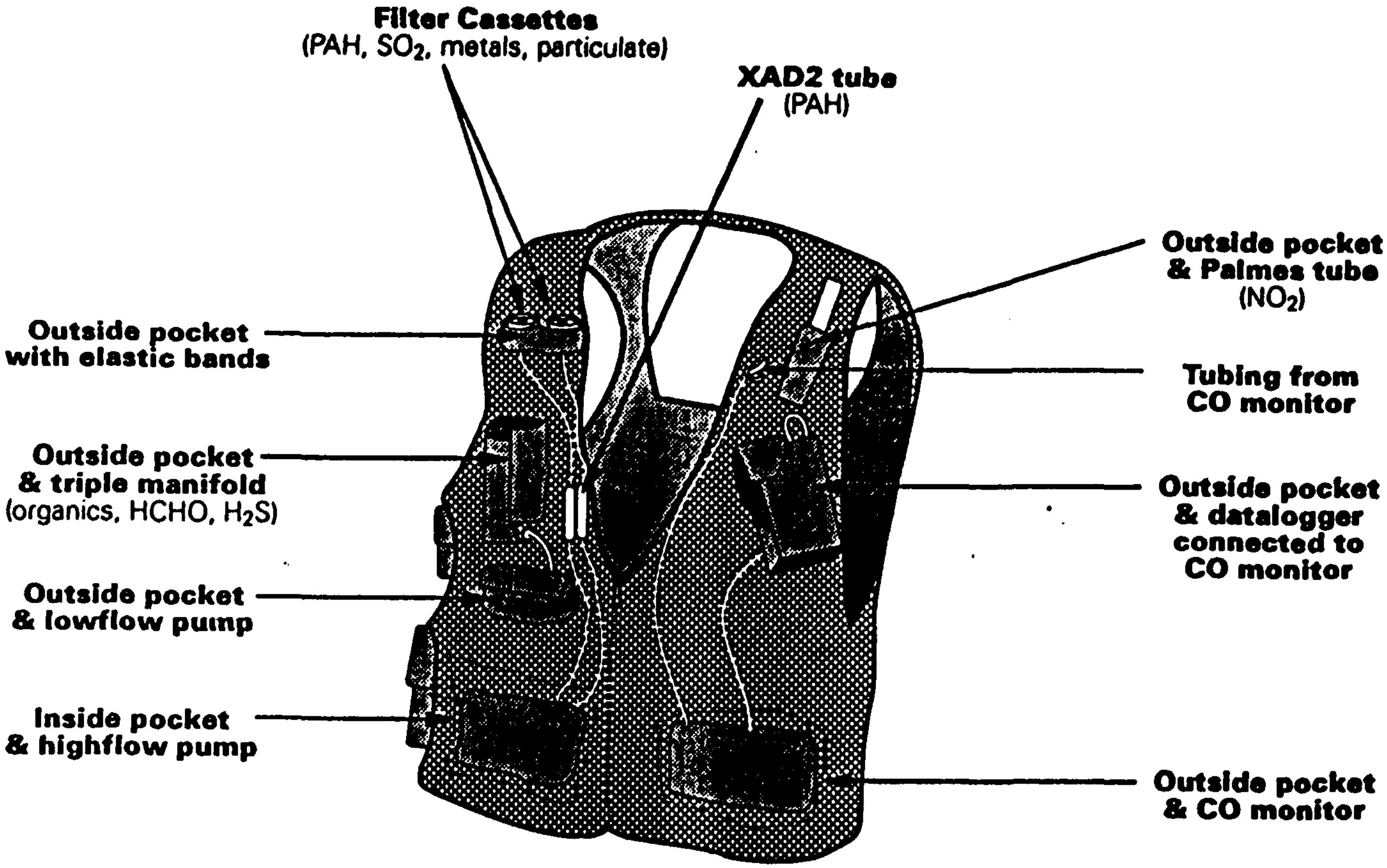

Figure 3. Breathing zone sampling system.

TABLE 7. SAMPLING AND ANALYTICAL TECHNIQUES

Analyte	Sampling Protocols			Analytical Protocols		Reference
	Device	Flow Rate (L/min)	Volume (L)	Method	Detection Limit ($\mu g/m^3$)	
Hydrogen Sulfide	Long duration color detector tubes	0.08	8-32	Colorimetric (in field)	700	SKC, Inc. Catalog Eighty Four, PA
Carbon Monoxide	Carbon monoxide analyzer	1	Continuous	Electrochemical detector	1200	Energy Efficiency Systems, Inc. Bethpage, NY
Hydrogen Cyanide	Ascarite II	0.3	30-120	Spectrophotometry at 578 nm	100	AIHAJ 7/78 (39)[15] EPA Total Cyanide[21] Method 335.2
Total Particulates	Matched weight filters	1.7	170-680	Gravimetric	500	NIOSH 0600[5]
Respirable Particulates	Dorr-Oliver Cyclone and matched weight filters	1.7	170-680	Gravimetric	500	NIOSH 0600[5]
Carbon Dioxide	Long duration color detector tubes	0.08	8-32	Colorimetric (in field)	900,000	SKC, Inc. Eighty Four, PA
Nitrogen Dioxide	Triethanolamine impregnated molecular sieve (GA)	0.05	5-20	Spectrophotometry at 540 nm	Less than 1500	P&CAM 231[4] AIHAJ 8/77 (38)
	Triethanolamine impregnated screen (Palmes tube) (BZ)	Passive	N/A	Spectrophotometry at 540 nm	184 (range = 1.2-80 ppm-hrs)	NIOSH 6700[5]

TABLE 7 (Continued)

Analyte	Sampling Protocols: Device	Sampling Protocols: Flow Rate (L/min)	Sampling Protocols: Volume (L)	Analytical Protocols: Method	Analytical Protocols: Detection Limit ($\mu g/m^3$)	Reference
Formaldehyde	N-Benzylethanolamine coated Chromosorb 102	0.05	5-20	Capillary column GC/ flame ionization detector	Less than 550	NIOSH 2502[5] (formerly P&CAM 354)
Aldehydes	Impinger with DNPH	1.0	100-400	HPLC	520	
	Tenax coated with DNPH reagent	0.2	20-80	HPLC	130	ADL Method[5] Development for Glutaraldehyde (NIOSH October 1985)
Sulfur Dioxide	Filters: mixed cellulose ester and potassium hydroxide impregnated cellulose	1.5	150-600	Ion chromatography	100	P&CAM 268[4]
Metals	Cellulose ester membrane filter	1.5	150-600	Inductively coupled argon plasma, atomic emission spectroscopy	2.5	NIOSH 7300[5]
Ammonia	Silica gel - sulfuric acid treated with filter	0.2	20-80	Ammonia specific electrode	1000	NIOSH S347[4]
PAH	XAD-2 sorbent PTFE filter	1.0	100-400	Ultrasonic extraction HPLC with UV/ fluorescence detection	1.0 for benzo(a)pyrene	NIOSH 5506[5]
NO_2-PAH	XAD-2 sorbent PTFE filter	1.0	100-400	GC with electron capture detection	0.25	ADL report to[22] Coordinating Research Council, Inc. February 1985

2.4 SAMPLING EQUIPMENT

The following portable air sampling equipment was used in this program for pollutan: monitoring:

TABLE 8. PORTABLE AIR SAMPLING EQUIPMENT

Gilian LFS 113D Low Flow Dual Mode Air Sampling Pump
Gilian DHFS 113A Dual High Flow Air Sampling Pump
Gilian Triple Variable Flow Controller Manifold
Gilian D800018 High Flow Calibrators
Gilian D800122 Low Flow Calibrator
Gilian C400384 Five Station Charger
Energy Efficient Systems Pocket 60 Carbon Monoxide Analyzer
Metrosonics Data Loggers, d1331
Metrosonics db653 Metroreader
Kurz Flowmeter, Model S541

2.5 SAMPLING LOGISTICS

2.5.1 Preparation

In preparation for the sampling trips, collection devices such as sorbent tubes and filters were purchased for the appropriate number of samples. Sorbent tubes and filters unavailable from commercial vendors were prepared and chemically coated (if necessary). Field equipment was shipped in secured foot lockers via truck directly to the installation or by Federal Express to the major airport closest to the installation. The program director and sampling coordinator picked up the equipment at the Federal Express office and transported it to the installation in a rented vehicle. The field team arrived at the military installation two days prior to actual sampling to set up equipment and supplies in the field laboratory provided by the Army. Sorbent tubes and filters were unpacked, segregated according to sampling method, and sample labels with a unique field identification code were attached. General purpose tubing (Tygon®) was cut to the appropriate length to connect the collection device to the sampling pump. The batteries in the air sampling pumps and electronic calibrating units were charged for 12-16 hours. A glass bubblemeter was assembled and filled for use as a primary standard to calibrate electronic flowmeters. Calibration data were recorded on a field form (Figure 4).

ARMY MEDICAL COMMAND FLOWMETER CALIBRATION DATA FORM

Date: Calibrator's Name: Signature:

Flow Meter Serial No.: Temperature (°F):

	Meter Flow (LPM)	Bubblemeter Volume (L)	Bubble Time (sec)	LPM Flow
Calibration @ ~0.02 (CO_2)				
(1)				
(2)				
(3)				
Calibration at ~0.05 (MS, NO_2)				
(1)				
(2)				
(3)				
Calibration at ~0.07 (Formaldehyde, H_2S)				
(1)				
(2)				
(3)				
Calibration at ~0.2 (NH_3)				
(1)				
(2)				
(3)				
Calibration at ~0.3 (HCN)				
(1)				
(2)				
(3)				
Calibration at ~1.0 (Aldehydes, PAH)				
(1)				
(2)				
(3)				
Calibration of ~1.7 (Metals, SO_2, TSP)				
(1)				
(2)				
(3)				

Figure 4. Army Medical Command flowmeter calibration data form.

Prior to the initiation of sampling, the air flow of the pumps was recorded with the collection device in line. The pumps were run for a maximum of 5 minutes during this calibration. The sampling pumps with collection media attached were then separated by location into small boxes (8 in. x 11 in. x 5 in.) and transported to the sampling location in a van or similar vehicle. The inlet side of the sampling device was capped to avoid direct contact with the air. General area sampling pumps were secured within the armored vehicle, end caps removed, and the starting time of sampling recorded. Breathing zone sampling vests were placed on the soldiers. After some initial discomfort, soldiers found that the sampling pumps were not noticed and did not restrain movements. Again, the starting time of each breathing zone sample was recorded.

2.5.2 Sampling Data Recording

At each sampling location, relevant sample information was recorded on a standardized form (Figure 5). The information recorded included:

a. Date, time, place and period of sampling (with start and stop times);
b. Type of armored vehicle sampled; and
c. Chemicals being sampled.

Through direct observation or discussion with the commander in each vehicle, a Weapon Firing Record (Figure 6) was completed to record the vehicle's activity including:

a. Weapon type;
b. Firing time; and
c. Number rounds fired.

2.5.3 Sampling Procedures

Generic sampling activities conducted during each sampling event are outlined in Table 9.

Table 10 lists the total number of samples collected during a typical sampling trip.

2.6 SAMPLE CUSTODY

2.6.1 Field Chain-of-Custody

Prior to collecting samples in the field, numbered sample tags were attached to each sample and the number recorded on the field data sheets.

ARMY MEDICAL COMMAND FIELD DATA FORM

Date: / / Sample Day: 1 2 Installation: S B C

Vehicle Type: M109 BFV M60 Vehicle: 1 2 3 4 5 Vehicle ID:_____

Calibration: Date / Time / Serial # / Initials

Before:_______/_______/_______/____After:______/_______/_______/_______

Sample Type: GA Location: FC C/O WH

Pump/Sect Chemical Init Flow Start Stop Fin Flow Label

H_____/T Metals

" /B Ald

H_____/T TSP

" /B RSP

L_____/1 Form

" /2 H_2S

" /3 NO_2

Chain of Custody

Samplers Name: Signature:
Shippers Name: Signature: Date:
Carrier Shipped by:
Receivers Name: Signature Date:

Figure 5. Army Medical Command field data form.

ARMY MEDICAL COMMAND WEAPON FIRING RECORD

Date:				
Facility:	Benning	Carson		Knox
Vehicle Type:	BFV	M109	M60	M1
Vehicle ID:				
Commander Name:				
Start Time of Exercise:				
End Time of Exercise:				

Weapon Firing Times

Weapon Type	Firing Time	# Rounds Fired

Figure 6. Army Medical Command weapon firing record.

TABLE 9. GENERIC FIELD ACTIVITIES

TASKS IN FIELD LAB	VEHICLE	ELAPSED TIME
Day Prior to Sampling: Label Collection Device/ Attach to Sampling Pump	1 - 6 analytes 2 - 6 analytes 3 - 9 analytes 4 - 9 analytes 5 - 6 analytes	150 minutes
Day of Sampling: Calibrate Sampling Pumps	1 - 6 analytes 2 - 6 analytes 3 - 9 analytes 4 - 9 analytes 5 - 6 analytes	150 minutes
Place Pumps in Protective Boxes and Vests		45 minutes
Transport Pumps to Training Site		
TASKS AT TRAINING LOCATION		
Install Sampling Pumps on Vehicles/Soldiers (Interact with Crew) Remove End Caps Activate Pumps		30 minutes
TASKS AFTER SAMPLING		
Remove Sampling Pumps on Vehicles/Soldiers Check/Deactivate Pumps Replace End Caps		20 minutes
Transport Pumps to Field Lab		
Recalibrate Sampling Pumps Cap Sampling Devices and Prepare for Shipment		120 minutes

TABLE 10. SAMPLES COLLECTED DURING A FIELD TRIP (2 DAYS)

Analyte	Number of Samples*				
	GA	BZ	1-Day Total	QC Samples	2-Day Total
SO_2	6	6	12	1	25
Organics	12	12	24	2	50
CO_2	6	--	6	1	13
NH_3	6	--	6	1	13
CO	12	12	24	--	48
Metals	6	6	12	1	25
Aldehydes	6	--	6	1	13
Total Particulate	6	6	12	1	25
Respirable Particulate	6	--	6	1	13
Formaldehyde	6	6	12	1	25
H_2S	6	6	12	1	25
HCN	6	--	6	1	13
NO_2	6	6	12	1	25
PAHs, N-PAHs	6	6	12	1	25

*Scheme assumes three breathing zone samples/vehicle. Where there are four breathing zone samples, numbers were proportionally higher. A fifth vehicle was often sampled to preclude loss of samples due to pump failure.

2.6.2 Storage/Shipping

At the completion of sampling, the field equipment was shipped to the next facility via a trucking company or air express service. The samples were placed in a plastic bag, wrapped in bubble wrap and placed in a gallon can with charcoal for delivery to the laboratory. A chain-of-custody record, with samples listed, accompanied the samples. Samples were kept refrigerated upon arrival in the laboratories.

2.6.3 Laboratory Custody

Sample information was entered into a computerized sample data base and each field sample assigned a unique, nonrecurring laboratory identification number. Samples were distributed to the appropriate chemists with chain-of-custody documentation and analyzed by the appropriate method (Figure 7).

U. S. Army Medical Command CHAIN OF CUSTODY
****

Case No.:56914-00 Date: 04/22/87

Analysis Required: Nitro PAHs By: NIOSH 5506

Lab Sample Numbers

18300	18301	18302	18303
18304	18305	18306	18307
18308	18310	18311	18312
18313	18316	18317	18318
18319	18320	18321	18322
18325	18326	18328	18329
18330	18331	18332	18333
18335	18336	18337	18338
18400			

SAMPLE LOG IN:

FROM: STANLEY LOCKE ______ ____________________ ______
Sample Custodian Emp.No. Signature Date

SAMPLE PREPARATION:
(e.g. Digestion with HCl, Dilutions with solvent, etc.)

TO: ____________________ ______ ____________________ ______
Name Emp.No. Signature Date

ANALYSIS: (e.g. AA,GC/FID, etc.)

TO: MARGARET RANDEL ______ ____________________ ______
Name Emp.No. Signature Date

STORAGE: (e.g. 15f/331, Cold Room)

TO: ____________________ ______ ____________________ ______
Name Emp.No. Signature Date

DATA REDUCTION:

TO: ____________________ ______ ____________________ ______
Name Emp.No. Signature Date

Lab Notebook No.:______________________ Page No. ________

REPORT SUBMISSION:

BY: ____________________ ______ ____________________ ______
Name Emp.No. Signature Date

Figure 7. Laboratory chain-of-custody form.

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3.0 RESULTS AND DISCUSSION

3.1 LOGISTIC ISSUES

3.1.1 Selection of Training Locations/Scenarios

Preliminary site visits were made to each installation selected by the U.S. Army Biomedical Research and Development Laboratory to coordinate sampling activities with field commanders and non-commissioned officers. Dates for sampling were identified and the firing scenarios were discussed to confirm that at least four vehicles would be present. The sampling periods and vehicle availability (Table 11) were documented as well as the location of the exercise (i.e., firing range). A sampling headquarters area was surveyed to confirm that at least 600 sq ft of easily accessible floor space and sufficient utilities, i.e., heat, lights, electricity, and water, were available for sampling equipment preparation.

The conditions of firing were selected to represent two training scenarios. Specifically, at Training and Doctrine Command (TRADOC) installations, soldiers are trained in a structured learning environment to operate/fire specific armored vehicles to fulfill the requirements of a specific MOS (Table 12). The training scenarios at Fort Sill (U.S. Army Field Artillery Board) and Fort Knox (U.S. Army Armor School) were designed for new recruits while the training scenario at Fort Benning (29th Infantry Regiment, Bradley Instructor Detachment) was designed to enhance the gunnery proficiency of selected field soldiers.

At Forces Command (FORSCOM) installations, MOS-qualified soldiers are trained in a field environment which simulates a battle scenario. These training scenarios were conducted at Fort Carson for both the M60 Tank and the M109 Howitzer (Table 13).

3.1.2 Selection of General Area Sampling Locations

Each vehicle type was investigated during an evaluation at Aberdeen Proving Ground, Maryland on October 30, 1986. The locations for placement of sampling pumps were selected so as to permit sampling of air in/near the working zone of vehicle crew, i.e., driver, commander, loader, and/or gunner. The placement of equipment was confirmed at field locations by surveying a typical training vehicle with a unit's gunnery sergeant and/or other staff. In all cases, the sampling equipment was placed in empty storage bins normally used to store weapons, ammunition or other devices (Table 14). A critical selection criterion was the requirement to place the sampling equipment out of the way so as to avoid interference with crew activities. In some cases, the sample collection devices, e.g., sorbent tubes, were suspended from brackets near the working area and connected by 3/8-in. I.D. Tygon® tubing to sampling pumps up to 3 ft away. In nearly all cases, the sampling location was only marginally acceptable in terms of size of available space and ease of installation. Flexible "bunji" cords and duct tape were needed to secure equipment to the vehicle.

TABLE 11. SUMMARY OF SITE INFORMATION

	Initial Trip	Full-Scale Sampling Trips					
Facility	Ft. Sill	Ft. Sill	Ft. Benning	Ft. Carson	Ft. Carson	Ft. Knox	Ft. Knox
Location	Lawton, OK	Lawton, OK	Columbus, GA	Colorado Springs, CO	Colorado Springs, CO	Radcliff, KY	Radcliff, KY
Scenario (Command)	TRADOC	TRADOC	TRADOC	FORSCOM	FORSCOM	TRADOC	TRADOC
Firing table (as appropriate)			VIIA, VIIIA	....	VIIIA		
Vehicle	M109	M109	M3	M109	M60	M1	M60
No. of vehicles available	6	6	5	2	24	7	7
No. of soldiers	5	5	3	4-5	4	4	4
SAMPLING SCHEDULE							
Arrival	01/17/87	03/15/87	03/29/87	04/05/87	05/04/87	07/26/87	08/16/87
Set-up	01/18/87	03/16/87	03/30/87	04/06/87	05/04/87	07/27/87	08/16/87
Sampling	01/20-21/87	03/17-18/87	03/31; 04/02/87	04/09/87	05/05; 05/07/87	07/28/87	08/17/87
Departure	01/22/87	03/19/87	04/03/87	04/10/87	05/08/87	07/29/87	08/18/87

TABLE 12. SELECTED TRADOC FACILITIES/SCENARIOS

Location/unit	Ft. Sill, OK U.S. Army Fld. Artillery Board	Ft. Knox, KY U.S. Army Armor School	Ft. Benning, GA 29th Inf. Rgt., Bradley Instructor Detachment Weapons Department
Type of vehicle	M109A3	M1E1	Bradley Fighting Vehicle M3
Description of firing event	13B MOS ALT - During their Tactical Week Exercises; two 2-day exercises	19K MOS OSUT Basic Armor Crewman Gunnery Stationary/Moving; 3 days	(M3) Master Gunner Course Ten 10-hr days; live fire exercise; crews fire tables V, VI, VII, VIII of Bradley Gunnery Tables
No. of crew members in vehicle	5-persons: section chief, gunner, assistant gunner, #1 man, radio/telephone operator	4-persons: instructor (tank cdr), driver, loader, gunner	4-persons: crew evaluator (instructor), commander, gunner, driver
No. of vehicles firing simultaneously	4-6 vehicles at one time	5-10 tanks (most often 5 tanks)	One vehicle moving down range; one on fire line; one on ready line
Firing frequency	360 rds of 155-mm fired over the entire week	Over 3 days, 5 tanks x 150 trainees x 6 rds plus additional 6 rds for 25 = 4650 rds	Practice: 350 rds/std/crse 5-7 rds/min; 350 rds/gun; 400 rds/day Training: 800 rds/std/crse 800 rds/gun; 3200 rds/day
No. of rounds by each vehicle	55 rds by each weapon	Main gun - 1050 rds 7.62-COAXM240 - 17,500 rds M85 50 Cal - 5250 rds	Practice: 14,000 rds/crse Training: 35,000 rds/crse
Type of ammo/weapon	155-mm HE M107	105-mm APDS (trng); 105-mm HEAT (trng); 7.62-COAXM240 (live); 50 cal (live)	Primary: 25-mm training practice tracer Secondary: 7.62-mm ammo live training

TABLE 12 (continued)

Location/unit	Ft. Sill, OK U.S. Army Fld. Artillery Board	Ft. Knox, KY U.S. Army Armor School	Ft. Benning, GA 29th Inf. Rgt., Bradley Instructor Detachment Weapons Department
Type of vehicle	M109A3	M1E1	Bradley Fighting Vehicle M2/M3
Crew activities	Load equipment; PMCS and prefire check	Break down ammo; dry fire exercise; live firing	PMCS on hull and turret; pre-fire check; upload ammo; Commo between crew and tower, boresighting and fire
Duration of training over a day	Day 1 0900-2200 hrs* Day 2 0630-1900 hrs* Day 3 0830-2200 hrs* Day 4 0630-1900 hrs* *Dinner at 1700-1800 hrs	0700-2400 daily 1130-1230 - lunch 1700-1800 dinner	0800-2000 hrs daily; no regular breaks; break fits around scenario; rotate lunch break and nonstop through lunch
Time between firing	15 min between firing at each target; 8 rds/vehicle	Approximately 5 minutes	3 to 4 minutes between targets
Hatch/door open?	Open - no NBC system no enclosure around gun hatch	Open except driver's hatch; weapons not buttoned up; ventilator off	Turret hatch open; driver's hatch closed; ventilation on. Access door to weapons closed; gun covers normally opened.

TABLE 13. SELECTED FORSCOM FACILITIES/SCENARIOS

Location/unit	Ft. Carson, CO 4th Division (AFZG) 3-29th	Ft. Carson, CO 4th Division (AFZG) 3rd Brigade
Type of vehicle	M109A3	M60
Description of firing event	Tactical Exercises; 2-day exercises	Tactical Exercise (Table VIII)
No. of crew members in vehicle	5-persons: commander, gunner, assistant gunner, #1 man, radio/telephone operator	4-persons: tank commander, driver, loader, gunner
No. of vehicles firing simultaneously	6 vehicles at one time	8-12 tanks
Firing frequency	84 rds of 155-mm fired over 24 hours	Over 1 day, 12 tanks on range for 30 minutes each
No. of rounds by each vehicle	14 rds	Main gun - 20 rds 7.62-COAX- 100 rds M85 50 Cal - 250 rds
Type of ammo/weapon	155-mm	105-mm APDS; 105-mm HEAT: 7.62-COAXM240; 50 Cal
Crew activities	Load equipment; PMCS and prefire check	Break down ammo; live firing
Duration of training over a day	0001-2400	0800-1800
Time between firing	Various times between firing at each target; 14 rds/vehicle	Approximately 2 minutes
Hatch/door open?	Open - no NBC system no enclosure around gun hatch	Open except driver's hatch; weapons not buttoned up

TABLE 14

DEPLOYMENT OF AREA SAMPLING EQUIPMENT

Vehicle	Area	Location
M60	Driver	Periscope box to right of driver's seat
	Commander	Shelf behind commander's seat
	Loader	Turret wall/gun firing circuit tester box
M3	Driver	Shelf to left and immediately behind driver (sampling tubes run into driver's area)
	Commander/Gunner	Shelf between radios behind commander
	Cargo/Troop Area	Ammo shelf on right behind turret
M1	Driver	On floor in front of driver's seat
	Commander	Shelf behind commander's seat
	Loader	Turret shelf to left of loader/space for auxiliary radio
M109	Driver	Floor below gun, sampling tubes run to driver's area
	Commander	Oddment tray near commander's seat
	Loader	Shelf to left of loader to rear of side hatch

Where space was available in vehicles, appropriate sampling pumps and carbon monoxide monitors were clustered in cardboard boxes (8 in. x 11 in. x 5 in.) which were covered with aluminum foil and bubble wrap to limit electromagnetic interference and physical shock. Up to six individual devices could be deployed in each box. Where space was limited, individual sampling devices were wrapped in bubble wrap and placed in vehicle storage bins.

3.1.3 Institutional Review Board

The U.S. Army Medical Command requested that the proposed work involving human participation in the experimental design be subjected to evaluation by an Institutional Review Board (IRB). This effort was completed on January 9, 1987 with submission of an HHS Form 596 (Figure 8) and backup documentation addressing the findings. This effort was undertaken to ensure that the work was conducted in accordance with regulations for the protection of human subjects (45 CFR46, as amended, January 26, 1981).

The IRB chairman reviewed the study plan involving military crews in several different vehicles, performing normal training duties while wearing a vest sample acquisition system. This activity was determined to be one of minimal or negligible risk. Additional data on human factor engineering of hatches and design of equipment was also reviewed. It was noted that the basic vest is used by aircrew who must expeditiously be able to exit confined spaces.

Two recommendations were made and conformed to:

(1) A brief written consent form (Figure 9) was prepared which asks the subject to volunteer, cites the need to obtain air samples to determine if there may be health hazards and warns that the apparatus may pose a minimal risk of catching on obstacles and causing a fall, or possibly encumbering a hasty exit in case of emergency. The written statement was to state explicitly that the subjects were under no obligation to participate in the test.

(2) A short written procedural guide (Figure 10) was prepared on how to use the vest, and precautions to take (no loose straps). Further, each person should practice at least one exit from their assigned position, prior to any actual testing, with additional practice if anyone snags or is impeded.

3.1.4 Variation in Site Sampling Protocols

The collection of discrete general area samples (3) and breathing zone samples (3 or 4) in each vehicle/type/command combination was disrupted on several occasions either by restrictions imposed by the field command or by failure of field sampling equipment. The field restrictions limited the number of firing events which could be sampled due to cancellation of an exercise or the inability to separately sample

OMB No. 0925-0637

DEPARTMENT OF HEALTH AND HUMAN SERVICES **PROTECTION OF HUMAN SUBJECTS ASSURANCE/CERTIFICATION/DECLARATION** ☐ ORIGINAL ☐ FOLLOWUP ☐ EXEMPTION (previously undesignated)	☐ GRANT ☐ CONTRACT ☐ FELLOW ☒ OTHER ☐ New ☐ Competing continuation ☐ Noncompeting continuation ☐ Supplemental APPLICATION IDENTIFICATION NO. *(if known)*

POLICY: A research activity involving human subjects that is not exempt from HHS regulations may not be funded unless an Institutional Review Board (IRB) has reviewed and approved the activity in accordance with Section 474 of the Public Health Service Act as implemented by Title 45, Part 46 of the Code of Federal Regulations (45 CFR 46—as revised). The applicant institution must submit certification of IRB approval to HHS unless the applicant institution has designated a specific exemption under Section 46.101(b) which applies to the proposed research activity. Institutions with an assurance of compliance on file with HHS which covers the proposed activity should submit certification of IRB review and approval with each application. (In exceptional cases, certification may be accepted up to 60 days after the receipt date for which the application is submitted.) In the case of institutions which do not have an assurance of compliance on file with HHS covering the proposed activity, certification of IRB review and approval must be submitted within 30 days of the receipt of a written request from HHS for certification.

1. TITLE OF APPLICATION OR ACTIVITY

ARTHUR D. LITTLE, INC., CAMBRIDGE, MA.

2. PRINCIPAL INVESTIGATOR, PROGRAM DIRECTOR, OR FELLOW

Kenneth T. Menzies

3. FOOD AND DRUG ADMINISTRATION REQUIRED INFORMATION *(see reverse side)* N/A

4. HHS ASSURANCE STATUS

☐ This institution has an approved assurance of compliance on file with HHS which covers this activity.

________ Assurance identification number ________ IRB identification number

☒ No assurance of compliance which applies to this activity has been established with HHS, but the applicant institution will provide written assurance of compliance and certification of IRB review and approval in accordance with 45 CFR 46 upon request.

5. CERTIFICATION OF IRB REVIEW OR DECLARATION OF EXEMPTION

☒ This activity has been reviewed and approved by an IRB in accordance with the requirements of 45 CFR 46, including its relevant Subparts. This certification fulfills, when applicable, requirements for certifying FDA status for each investigational new drug or device. *(See reverse side of this form.)*

2 JAN 87 Date of IRB review and approval. *(If approval is pending, write "pending." Followup certification is required.)*
(month/day/year)

☐ Full Board Review ☒ Expedited Review

☐ This activity contains multiple projects, some of which have not been reviewed. The IRB has granted approval on condition that all projects covered by 45 CFR 46 will be reviewed and approved before they are initiated and that appropriate further certification *(Form HHS 596)* will be submitted.

☐ Human subjects are involved, but this activity qualifies for exemption under 46.101(b) in accordance with paragraph ______ *(insert paragraph number of exemption in 46.101(b), 1 through 5)*, but the institution did not designate that exemption on the application.

6. **Each official signing below certifies that the information provided on this form is correct and that each institution assumes responsibility for assuring required future reviews, approvals, and submissions of certification.**

APPLICANT INSTITUTION	COOPERATING INSTITUTION
NAME, ADDRESS, AND TELEPHONE NO. Arthur D. Little, Inc. Acorn Park Cambridge, MA 02140	NAME, ADDRESS, AND TELEPHONE NO.
NAME AND TITLE OF OFFICIAL *(print or type)* William S. Augerson, M.D. VP ADL - Chairman, IRB	NAME AND TITLE OF OFFICIAL *(print or type)*
SIGNATURE OF OFFICIAL LISTED ABOVE *(and date)* William S. Augerson	SIGNATURE OF OFFICIAL LISTED ABOVE *(and date)*

HHS 596 (Rev. 1/82) *(If additional space is needed, please use reverse side under "Notes.")*

Figure 8. HHS Form 596.

CONSENT FORM

Participation in an Air Sampling Study in Armored Vehicles
Contract No. DAMD17-86-C-6245

As explained in your preliminary briefing, Arthur D. Little, Inc. is conducting an air sampling study in armored vehicles for the U.S. Army Medical Research and Development Command. Representatives from the U.S. Army Medical Research and Development Command may inspect the records of this program. We request your participation in this study. Specifically, we request that you wear an Army vest, modified to contain portable air sampling equipment, for a period of approximately two to eight hours during a normal training exercise.

While you are wearing this vest, there is a small chance that it could catch on obstacles, cause a fall, or encumber a hasty exit in case of emergency. Both Arthur D. Little, Inc. and the U.S. Army Medical Research and Development Command believe these risks are minimal or negligible. You have practiced an exit from the vehicle to acquaint you with the vest.

If you have any questions about this program, please contact K. Menzies, the principle investigator, at 617-864-5770, x3017. Questions regarding research subjects' rights should be addressed to the Post Judge Advocate at ________.

I understand that I am volunteering to wear the vest. No one can require me to do so, and if I do not wish to wear the vest, no action can be taken against me.

________________	________
Name	Date
________________	________
Name	Date
________________	________
Name	Date
________________	________
Name	Date

Figure 9. Consent form.

PROCEDURES FOR USE OF AIR SAMPLING VEST

1. Accept vest from Arthur D. Little, Inc. staff.

2. Put vest on.

3. Close zipper.

4. Allow Arthur D. Little, Inc. staff or Army associate to adjust vest:

   - Open velcro cover on back;
   - Adjust draw string until vest is tight but does not restrict your movement; and
   - Close velcro cover.

5. Check that no strings or belts hang from vest. Tie in place, if necessary.

6. Practice entering and exiting the vehicle once to become familiar with the feel of the vest.

7. Wear vest for designated period.

8. Do not manipulate sampling equipment on vest.

9. When requested, remove vest and give it to Arthur D. Little, Inc. staff.

Figure 10. Procedures for use of air sampling vest.

breathing zones of selected crew members, e.g., gunner and loader, due to space and time constraints. The equipment problems limited the number of samples collected due to failure of pumps as a result of vibrational stress, precipitation, restriction of sample flow tube in vests, or high pressure drop of a sampling device, i.e., PAH, SO_2.

Various problems occurred at individual forts and were dealt with as efficiently as possible with a goal of minimizing their impact on the sampling program. The problems are summarized below in the order that they were observed. This information is critical to an understanding of the difficulties which can occur during field sampling of military firing exercises. It is provided so as to limit similar problems in future field monitoring programs.

3.1.4.1 Segregation of Breathing Zone Samples

An occasional problem observed during the first site visit to Fort Sill involved the inability to obtain breathing zone samples from soldiers carrying out a single function (i.e., driver, loader, gunner, or commander). Due to the training nature of the activities at Fort Sill and Fort Knox, many soldiers sequentially rotate functional positions within the M109, M1 or M60, including getting out of the vehicle entirely when another soldier rotates in. Potential solutions to this problem included the following options:

(1) Soldiers in a vehicle switch sampling vests during rotation from one position to another, e.g., loader to gunner;

(2) Soldiers switch vests only when leaving vehicle after acting as both loader and gunner; and

(3) Sampling equipment is removed after each round of firing in each vehicle.

Time and space constraints precluded easy switching of vests inside the weapons handling area. Sample volume constraints precluded the frequent (each round) replacement of sampling equipment. Therefore, as a soldier rotated from the loader position to the gunner position, the vest was not changed. However, as the soldier exited the vehicle, the vest was removed and donned by the next soldier. The driver vest was exchanged with the next soldier upon his rotation into that position. The commander vest was worn continuously by the instructor who remained in that position throughout the exercise.

As a result of these movements, the interpretation of the breathing zone results from vehicles at TRADOC facilities must include an understanding that loader samples represent an integration of exposure in both the loader and gunner positions. Similar situations occurred in other vehicles. Breathing zone samples thus may represent the exposure in various positions/functions in these vehicles (Table 15).

TABLE 15

REPRESENTATION OF FUNCTIONAL CREW POSITIONS
IN DISCRETE VEHICLE TYPES

Fort	Vehicle	Breathing Zone Sample Code Driver (BD)	Commander (BC)	Loader (BL)	Gunner (BG)
Sill	M109	Instructor	Trainee	Trainee	--
Benning	M3	Staff	Trainee	Trainee	--
Carson	M109	Driver	Commander	Loader	--
Carson	M60	Driver	Commander	Loader	Gunner
Knox	M1	Trainee	Instructor	Trainee	Trainee
Knox	M60	Trainee	Instructor	Trainee	Trainee

3.1.4.2 Documentation of Firing Intensity and Exercise Duration

For pollutants other than carbon monoxide, another significant issue relates to the correlation of the mass of pollutant found on a sampling collection device to the volume of air sampled and the firing intensity. A vehicle crew may conduct maneuvers/firing over an elapsed time of up to 24 hours per day, although only a small amount of the total time is spent firing weapons. In order to track the frequency of firing, and define the volume of sample air collected during firing, a firing log was maintained. This included a record of firing time and type/number of shells fired.

The firing intensity and duration is potentially significant to the testing of hypotheses about the agreement of chemical data within vehicle types and commands. Specifically, the number of shells fired per unit time or mass of propellant expended may determine the amount of pollutant released into the vehicle and subsequently collected on the sampling devices. On the basis of this observation, these variables were tested as covariates to explain variation in pollutant concentration within vehicle types.

Additionally, it is apparent that the total duration of a daily training exercise may be significantly longer than the time when soldiers are exposed to weapon combustion products during firing. For each training scenario evaluated during this program, the differences between firing duration (pollutant exposure duration) and exercise duration (sample collection duration) were frequently pronounced. During sampling of the M3 at Fort Benning, for example, the firing time was as short as 20 minutes even though the duration of the entire exercise was up to 2 hours. In this case, two crews utilized the same vehicle for separate 20-minute firing events over a two-hour period during which the sampling equipment was continuously operated.

In order to address the potential range of exposures likely to be received by soldiers during the "typical" training scenarios monitored in this program, two time-weighted concentrations have been calculated.

Following sample collection, the sampling devices were recovered, sealed, and returned to the laboratory for analysis. In the laboratory, the sampling devices were desorbed and analyzed (Appendix A) so that the total quantity (Q) of analyte collected on each device could be determined.

The total quantity of analyte was converted to a calculated concentration of analyte in the air inside the vehicle by making one of two limiting assumptions. Under one of these assumptions, a concentration labeled FIRECONC was calculated as:

$$\text{FIRECONC } (\mu g/m^3) = \frac{Q}{R \times T_f}$$

where,

Q - total quantity of analyte collected (μg);
R - sampling rate (m^3/min); and
T_f - total elapsed time of active firing (min).

Thus, FIRECONC is the average concentration that would have been observed if weapons' combustion product analytes were generated and present in the air only during the periods of active weapons firing with less than 60 minutes between rounds.

A second limiting concentration, TOTCONC, was calculated as:

$$\text{TOTCONC } (\mu g/m^3) = \frac{Q}{R \times T_t}$$

where,

Q,R - as above
T_t - total sampling time, min.

Thus, TOTCONC is the concentration that might have been present in the vehicle air if the combustion products had been generated continuously, rather than in sporadic bursts of firing activity.

Neither FIRECONC nor TOTCONC provides an exact estimate of the air concentration to which soldiers were exposed. However, taken together the two calculated concentrations bracket the effective exposure range over reasonable exposure intervals. Some members of the crew, e.g., commander/instructor, are exposed to pollutants during the entire exercise duration. However, most members of the crew, e.g., trainees, are outside of the vehicle during some fraction of the total exercise duration to participate in work parties, attend meetings or take meal breaks. In every case, these concentration extremes are reported to assist in the evaluation of potential exposure. With the exception of CO, neither concentration represents maximum instantaneous exposure. However, they do represent useful estimates of potential exposure inside a vehicle. Cumulative exposure would be much lower where activity outside the vehicle is significant.

The firing time (firing duration/FIRECONC sampling period), total time (exercise duration/TOTCONC sampling period), and firing intensity data, i.e., number of large caliber shells fired (155 mm, 105 mm or 25 mm) and small caliber shells fired (7.62 mm and 50 cal) and propellant mass of large shells and small shells for each exercise, are documented in Table 16.

NOTE: For carbon monoxide only, which was monitored continuously, FIRECONC and TOTCONC were not used. For this analyte, the PEAK CO concentration is the highest daily 10-second reading observed for a given vehicle. The MEAN PEAK CO is the average of the PEAKS for all vehicles of one type on one day. Both PEAK and MEAN PEAK are higher measures of CO than FIRECONC would have been. The AVERAGE CO concentration is the cumulative average value over the duration of the exercise. It is equivalent to TOTCONC.

TABLE 16. EXERCISE/FIRING DATA

Fort	Vehicle Type	Day	Vehicle No.	Large Caliber (No.)	Large Mass (kg)	Small Caliber (No.)	Small Mass (kg)	Duration Firing (min)	Duration Exercise (min)
Sill	M109	1	1	12	144.00	0	0.00	158	420
Sill	M109	1	2	16	192.00	0	0.00	162	420
Sill	M109	1	3	16	192.00	0	0.00	131	420
Sill	M109	2	1	16	192.00	0	0.00	147	210
Sill	M109	2	2	18	216.00	0	0.00	152	210
Sill	M109	2	3	17	204.00	0	0.00	154	240
Sill	M109	2	4	16	192.00	0	0.00	156	210
Sill	M109	3	1	7	84.00	0	0.00	118	331
Sill	M109	3	2	12	144.00	0	0.00	118	320
Sill	M109	3	3	12	144.00	0	0.00	141	340
Sill	M109	3	4	16	192.00	0	0.00	79	347
Sill	M109	3	5	13	156.00	0	0.00	120	334
Sill	M109	4	1	10	120.00	0	0.00	56	100
Sill	M109	4	2	8	96.00	0	0.00	62	116
Sill	M109	4	3	10	120.00	0	0.00	58	107
Sill	M109	4	4	10	120.00	0	0.00	60	162
Sill	M109	4	5	8	96.00	0	0.00	61	120
Benning	M3	1	1	90	9.00	400	1.20	40	160
Benning	M3	1	2	90	9.00	321	0.96	40	199
Benning	M3	1	3	45	4.50	194	0.58	40	180
Benning	M3	1	4	90	9.00	334	1.00	40	263
Benning	M3	1	5	120	12.00	367	1.10	40	180
Benning	M3	2	1	117	11.70	350	1.05	60	280
Benning	M3	2	2	113	11.30	350	1.05	60	306
Benning	M3	2	3	56	5.60	150	0.45	60	300
Benning	M3	2	4	114	11.40	215	0.65	60	220
Benning	M3	2	5	107	10.70	275	0.83	60	90

TABLE 16 (continued)

Fort	Vehicle Type	Day	Vehicle No.	Large Caliber (No.)	Large Mass (kg)	Small Caliber (No.)	Small Mass (kg)	Duration Firing (min)	Duration Exercise (min)
Carson	M109	1	1	12	144.00	0	0.00	66	240
Carson	M109	1	2	2	24.00	0	0.00	89	288
Carson	M60	1	1	11	62.70	150	1.50	20	99
Carson	M60	1	2	12	68.40	105	1.05	20	116
Carson	M60	1	3	10	57.00	150	1.50	20	96
Carson	M60	1	4	13	74.10	150	1.50	20	263
Carson	M60	1	5	6	34.20	150	1.50	20	75
Carson	M60	2	1	12	68.40	150	1.50	20	40
Carson	M60	2	2	16	91.20	150	1.50	20	65
Carson	M60	2	3	11	62.70	150	1.50	20	130
Carson	M60	2	4	6	34.20	150	1.50	20	260
Carson	M60	2	5	10	57.00	150	1.50	20	260
Knox	M1	1	1	15	85.50	200	0.60	133	165
Knox	M1	1	2	21	119.70	30	0.09	115	174
Knox	M1	1	3	22	125.40	250	0.75	134	184
Knox	M1	1	4	18	102.60	100	0.30	115	172
Knox	M1	2	1	28	159.60	150	0.45	191	270
Knox	M1	2	2	24	136.80	100	0.30	184	262
Knox	M1	2	3	25	142.50	100	0.30	190	225
Knox	M1	2	4	30	171.00	0	0.00	184	215
Knox	M60	1	1	27	153.90	525	1.58	290	375
Knox	M60	1	2	27	153.90	300	0.90	294	360
Knox	M60	1	3	31	176.70	300	0.90	292	370
Knox	M60	1	4	27	153.90	550	1.65	286	365

3.1.5 Sampling Equipment

At the end of each firing exercise, the equipment was checked to confirm that all pumps were operating. During several sampling exercises, it was observed that some high flow pumps used to simultaneously collect PAH samples and SO_2 samples had failed. The cause of the failure is uncertain but it was probably due to the pressure drop of the PAH or SO_2 devices. A reduced flow rate (~0.5 Lpm) and a Teflon®-coated glass filter were used to limit this problem.

The commercially available CO_2 tube used for field sampling was observed to be expended after only four hours of sampling. In order to use this device reliably, the sampling time or sampling rate was reduced.

Other vest equipment problems were (1) the short length of the sorbent tube pocket, (2) shutting off of the CO monitor switches due to body motion, and (3) the reverse operation of the vest zipper (female versus male zipper). These problems were corrected as indicated below:

(1) The mesh top of the sorbent pocket was cut to permit the GC/MS tubes to extend through the pocket top. The tubes did not extend so far as to pose a danger to the soldier wearing the vest.

(2) Duct tape was placed over the CO monitor switches after activation. As a result, they all operated reliably.

(3) It appears that the vest was turned inside out to facilitate placement of pockets. This inadvertently makes it confusing to put the vest on since one must hold the side of the zipper opposite that normal for males. This problem does slow down donning the vest but is manageable.

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3.2 POLLUTANT CONCENTRATIONS IN ARMORED VEHICLES

3.2.1 Data Base

As a result of this field monitoring program, an extensive chemical data base consisting of thousands of concentration measurements for a total of 178 compounds has been generated. These data are segregated by training scenario (i.e., TRADOC, FORSCOM), fort (Benning, Carson, Knox, Sill), vehicle type (M1, M3, M60, M109), location within vehicle (commander, driver, gunner, loader), and general area versus breathing zone. The data are provided in the subsequent text or in Appendix B. As noted in Section 3.1.4.2, two concentration extremes designated TOTCONC and FIRECONC have been calculated for each measurement. Since each training exercise is somewhat different with respect to the movement of individual soldiers, instructors or vehicle operators, these concentration levels were calculated in the hope of bracketing average concentrations generated during firing periods (FIRECONC) or total exercise periods (TOTCONC). These concentrations are integrated, not instantaneous measurements, for all pollutants except carbon monoxide (CO). In the case of CO, Peak concentration in each sampling location was determined instrumentally as the maximum ten-second integrated concentration observed during the entire exercise. Average CO concentration in each sampling location was determined instrumentally as time-weighted average over the entire exercise. In the following section, concentrations (FIRECONC and TOTCONC) for individual compounds are tabulated along with field code which describes sampling location as indicated in Table 17. The mean concentrations for each pollutant in all sampling locations are graphically represented across vehicle types. The mean concentrations for discrete, as well as all, sampling locations are tabulated (SAS, Inc. PROC TABULATE) to assist in statistical comparison (Appendix C). All raw sample concentration data are provided in Appendix B. The tabulated (PROC TABULATE) mean concentrations include non-detectable levels as non-zero values. That is, any sample pollutant concentration which was observed to be below the detection limit was reported to be equal to the detection limit (e.g., 10 $\mu g/m^3$). The detection limit in this report is that concentration which can be differentiated from a blank sample with 95% confidence. As a result of this criterion, reported mean concentrations are higher than the actual concentrations. Where a significant number of sample concentrations (>25%) are non-detectable, a discussion/comparison of mean concentrations is not given and, alternatively, a discussion of the concentration range of individual sample results (Appendix B) is given. Note that the detection limits are inversely proportional to the sampling volume and thus vary for each vehicle and vehicle type.

3.2.2 Compound-Specific Concentration Ranges

Fundamental to any assessment of the exposure of crew members in armored vehicles to specific pollutants is documentation of the concentration of the pollutant in the environment, i.e., vehicle and/or surrounding environment, and an understanding of the movement of the

TABLE 17. FIELD CODE EXPLANATION

Example: PSM11SACPAHF

Key							
P	S	M	1	1	A	C	PAHF
Sampling Trip Preliminary Full	Installation: Ft. Sill Ft. Benning Ft. Carson Ft. Knox	Vehicle: M109(M) M3(B) M60(T) M1(A)	Day 1,2	Vehicle: 1,2,3,4	Type: A-Area B-Breathing	Location: C-Commander D-Driver L-Loader G-Gunner	Analyte

Code	Analytes
PAHF	Filter for PAHs
PAHS	Sorbent (XAD-2) PAHs
SO2	Filter with band for SO_2
MS1	Sorbent (Tenax®/Ambersorb®)
MS2	Sorbent tube replicate
CO	CO monitor
NH3F	Filter for NH_3
NH3S	Sorbent (silica gel SKC 226-10-06)
CO2	Draeger tube for CO_2
NO2	Passive dosimeter - breathing zone
	Sorbent (molecular sieve SKC-226-40) - general area
H2S	Draeger tube for H_2S
FOR	Sorbent (coated XAD-2 - Supelco 2-0261)
TSP	Total suspended particulate (matched weight filter)
MET	Filter for metals
RSP	Respirable suspended particulate (matched filter, cyclone)
ALD	Impinger/sorbent, aldehyde
HCN	Sorbent (Ascarite)

crew within this environment. This experimental program was designed to collect preliminary data on potential pollutant exposure by collecting general area and breathing zone samples under specific training and/or battle simulation scenarios frequently conducted at U.S. Army facilities. Therefore, a discrete time/motion study was not conducted and the monitoring was conducted under exposure scenarios which represented "typical" U.S. Army activities.

On the basis of the experimental results, it is appropriate to report the range of concentrations of the selected compounds within four specific types of armored vehicles operated under specific training scenarios. It is possible to compare these concentrations against available health guidelines (Table 18). However, it is not appropriate to attempt to make rigorous risk assessments with respect to the observed concentrations in direct comparison to workplace standards (ACGIH threshold limit values, TLV). The U.S. Army training scenario is certainly not directly comparable to a normal 40-hour work week scenario. An interpretation of risk associated with typical training scenarios may be made with respect to levels of short-term acute hazard [ACGIH Short-Term (15 minute) Exposure Limit (STEL); National Research Council (NRC) Emergency and Continuous Exposure Limits] or cautiously assessed on the basis of long-term toxicological information. The NRC exposure limit is generally understood as a level that, if exceeded for 10-minute, 60-minute, or longer intervals, may be regarded as constituting an acute risk to health.

The graphical and tabular concentration summaries for each pollutant are provided at the end of this section (3.2.2).

3.2.2.1 Carbon Monoxide

The PEAK (10-second) carbon monoxide (CO) concentrations ranged from 10 to >2000 ppm in all the vehicles surveyed. The MEAN PEAK CO concentrations (i.e., average of daily peaks for all vehicles of one type) were lowest in the M109 (400 ppm) and highest in the M1 (1500 ppm) (Figure 11). The maximum PEAK CO levels (i.e., highest daily peak for all vehicles of one type) frequently exceeded the upper range of the monitor, approximately 2000 ppm, in the M1 and M60 tanks, but the durations of these maxima were generally less than 1 minute. (The NRC short-term Emergency Exposure Limit for CO is 1500 ppm for 10 minutes exposure and the NIOSH STEL is 400 ppm for 15 minutes.) There was a single instance (loader/breathing zone/M1 tank) in which the CO reading exceeded 1500 for a continuous period of almost 40 minutes. These elevated readings were observed starting at time zero of the test and other CO monitors in the same vehicle (other crew positions and loader/area sampler) gave consistently lower readings. However, there is no inherent reason to reject the data from the loader/breathing zone instrument. Also, there were several observations for M1 and M60 tanks in which the CO concentration averaged above 400 ppm (up to 760 ppm) for a 15-minute period. On the other hand, the average CO concentrations over the total exercise duration ranged from 4 to 44 ppm in all vehicles (Figure 12 and Table 19. In Table 19, the values listed in the FIRECONC column are really 10-second PEAK values.) The PEAK CO concentrations are clearly related to firing within the vehicles; PEAK concentrations occur shortly after a single firing event or during firing events separated by only a few (<5) minutes (Figure 13).

TABLE 18. HEALTH STANDARDS FOR TOXIC COMPOUNDS[25,26]

	NRC[25]	TLV-TWA[26] ppm	TLV-TWA[26] mg/m³	STEL[26] ppm	STEL[26] mg/m³
Acetaldehyde	--	100	180	150	270
Acrolein	0.1 ppm (10 min)	0.1	0.25	0.3	0.8
Ammonia	100 ppm (60 min)	25	18	35	27
Benzene	50 ppm (60 min)	10	30	--	--
Cadmium salts	--	--	0.05	--	--
Carbon dioxide	--	5000	--	30,000	--
Carbon monoxide	1500 ppm (10 min)	50	--	400	--
Chlorobenzene	--	75	350	--	--
Chromium salts	--	--	0.5	--	--
Copper salts	--	--	1	--	--
Dichlorobenzene	--	75	450	110	675
Formaldehyde	--	1	1.5	2	3
Hydrogen cyanide	--	ceiling 10	10	--	--
Hydrogen sulfide	50 ppm (10 min)	10	14	15	21
Iron oxide	--	--	5	--	--
Lead salts	--	--	0.15	--	--
Magnesium oxide	--	--	10	--	--
Manganese	--	--	5	--	--
Mercury	0.2 ppm (24 hr)	--	0.1	--	--
Molybdenum salts	--	--	5	--	--
Naphthalene	--	10	50	15	75
Nickel salts	--	--	1	--	--
Nitric oxide	--	25	30	--	--
Nitrogen dioxide	5 ppm (10 min)	3	6	5	10
Silver salts	--	--	0.01	--	--
Sulfur dioxide	30 ppm (10 min)	2	5	5	10
Tin salts	--	--	2	--	--
Vanadium oxide	--	--	0.05	--	--
Zinc chloride	--	--	1	--	--
Zirconium salts	--	--	5	--	--
Particulates	--	--	10	--	--

-- = Not available

TLV-TWA = Threshold limit value-Time weighted average (8 hr)

STEL = Short-term exposure limit (15 min)

NRC = National Research Council Emergency and Continuous Exposure Limit

3.2.2.2 Carbon Dioxide

The mean carbon dioxide (CO_2) concentrations (Table 20) observed for all sampling positions in each fort/vehicle type over the total exercise periods (TOTCONC) ranged from greater than 556 ppm to 828 ppm (Figure 14). The mean CO_2 concentrations observed during the firing periods (FIRECONC) ranged from greater than 283 ppm to 3230 ppm (Figure 15). The maximum FIRECONC concentration (5710 ppm) was associated with the shortest firing period (20 minutes) in the M60 at Fort Carson. This concentration is significantly lower than the STEL level (30,000 ppm). The atmospheric CO_2 concentration is 350 ppm and the TLV is 5000 ppm.

3.2.2.3 Hydrogen Sulfide

Hydrogen sulfide (H_2S) was detected in all vehicle types but in much fewer than 50% of the samples in the M109 and M3 (Appendix B). The mean hydrogen sulfide concentrations (Table 21) observed for all sampling positions in each fort/vehicle type over the total exercise periods (TOTCONC) ranged from below the detection limit (~100 ppb) to 288 ppb (Figure 16). The H_2S concentrations observed during the firing period (FIRECONC) ranged from below the detection limit (~200 ppb) to 1010 ppb (Figure 17). The maximum FIRECONC concentration (6120 ppb) was observed in the M60 tank at Fort Carson. These levels are less than the TLV (10,000 ppb.)

3.2.2.4 Hydrogen Cyanide

Hydrogen cyanide (HCN) was detected in each vehicle type but in much fewer than 50% of the samples (Appendix B). The mean hydrogen cyanide concentrations (Table 22) observed for all sampling positions in each fort/vehicle type observed over the total exercise periods (TOTCONC) ranged from below the detection limit (~100 $\mu g/m^3$) to 302 $\mu g/m^3$ (Figure 18). The mean HCN concentrations observed during the firing period (FIRECONC) ranged from below the detection limit (~200 $\mu g/m^3$) to 1070 $\mu g/m^3$ (Figure 19). The maximum FIRECONC concentration (1280 $\mu g/m^3$) was observed in an M1 at Fort Knox. These levels are less than the TLV ceiling (10,000 $\mu g/m^3$).

3.2.2.5 Nitric Oxide

Nitric oxide (NO) was detected in all vehicle types but in only one sample in the M1 at Fort Knox (Appendix B). The mean nitric oxide concentrations (Table 23) observed for all sampling positions in each fort/vehicle type over the total exercise periods (TOTCONC) ranged from below the detection limit (~300 $\mu g/m^3$) to 1090 $\mu g/m^3$ (Figure 20). The mean NO concentrations observed during the firing period (FIRECONC) ranged from below the detection limit (~600 $\mu g/m^3$) to 3260 $\mu g/m^3$ (Figure 21). The maximum FIRECONC concentration (6430 $\mu g/m^3$) was observed in an M60 at Fort Carson. These levels are less than the TLV (30,000 $\mu g/m^3$).

3.2.2.6 Nitrogen Dioxide - General Area

Nitrogen dioxide (NO_2) was detected in all vehicle types but in only one sample in the M1 at Fort Knox (Appendix B). The mean nitrogen dioxide concentrations (Table 24) observed for all general area locations in each fort/vehicle type over the total exercise periods (TOTCONC) ranged from below the detection limit (~500 $\mu g/m^3$) to 1030 $\mu g/m^3$ (Figure 22). The mean NO_2 concentrations observed during the firing period (FIRECONC) ranged from below the detection limit (~1000 $\mu g/m^3$) to 3540 $\mu g/m^3$ (Figure 23). The maximum FIRECONC concentration (8430 $\mu g/m^3$) was observed in an M60 at Fort Carson. These levels are occasionally greater than the TLV (6000 $\mu g/m^3$) but less than the STEL (10,000 $\mu g/m^3$).

3.2.2.7 Nitrogen Dioxide - Breathing Zone

The mean nitrogen dioxide (NO_2) concentrations (Table 25) observed in breathing zone locations in each fort/vehicle type over the total exercise periods (TOTCONC) ranged from below the detection limit (~100 $\mu g/m^3$) to 955 $\mu g/m^3$ (Figure 24). The mean NO_2 concentrations observed during the firing period (FIRECONC) ranged from below the detection limit (~200 $\mu g/m^3$) to 4660 $\mu g/m^3$ (Figure 25). The maximum FIRECONC concentration (17,900 $\mu g/m^3$) was observed in an M60 at Fort Carson. The NO_2 concentrations are occasionally greater than the TLV (6000 $\mu g/m^3$) and are consistent with the nitrogen dioxide general area samples.

3.2.2.8 Formaldehyde

Formaldehyde (HCHO) was detected in all vehicle types but in fewer than 10% of the samples in the M109 and M60 at Fort Carson (Appendix B). The mean formaldehyde concentrations (Table 26) observed for all sampling positions in each fort/vehicle type over the total exercise periods (TOTCONC) ranged from below the detection limit (~50 $\mu g/m^3$) to 99.9 $\mu g/m^3$ (Figure 26). The mean HCHO concentrations observed during the firing period (FIRECONC) ranged from below the detection limit (~100 $\mu g/m^3$) to 389 $\mu g/m^3$ (Figure 27). The maximum FIRECONC concentration (499 $\mu g/m^3$) was observed in an M1 at Fort Knox. These levels are less than the TLV (1500 $\mu g/m^3$).

3.2.2.9 Ammonia

Ammonia (NH_3) was detected in all vehicle types but in only two samples in the M109 and in about one-third of the samples in the M3. The mean ammonia concentrations (Table 27) observed for all sampling positions in each fort/vehicle type over the total exercise periods (TOTCONC) ranged from below the detection limit (~100 $\mu g/m^3$) to 359 $\mu g/m^3$ (Figure 28). The mean NH_3 concentrations observed during the firing period (FIRECONC) ranged from below the detection limit (~200 $\mu g/m^3$) to 545 $\mu g/m^3$ (Figure 29). The maximum FIRECONC concentration (1680 $\mu g/m^3$) was observed in an M60 at Fort Carson. These levels are less than the TLV (18,000 $\mu g/m^3$).

3.2.2.10 Total Suspended Particulates

The mean total suspended particulates (TSP) concentrations (Table 28) observed for all sampling positions in each fort/vehicle type over the total exercise periods (TOTCONC) ranged from below the detection limit (~500 $\mu g/m^3$) to 1320 $\mu g/m^3$ (Figure 30). The mean TSP concentrations observed during the firing period (FIRECONC) ranged from below the detection limit (~1000 $\mu g/m^3$) to 4870 $\mu g/m^3$ (Figure 31). The maximum FIRECONC concentration (55,600 $\mu g/m^3$) was observed in an M3 at Fort Benning. The mean concentrations during firing are all less than one half the TLV (10,000 $\mu g/m^3$) for nuisance dust. Maximum FIRECONC concentrations were observed to exceed the TLV in the M109, M3 and M60.

3.2.2.11 Respirable Suspended Particulates

Fewer than 20% of the samples of respirable (<10 μm) suspended particulates (RSP) yielded concentrations in excess of the detection limit (~500 $\mu g/m^3$). The concentrations (Appendix B) observed over the total exercise periods (TOTCONC) and firing periods (FIRECONC) were all less than 1880 $\mu g/m^3$ and 3320 $\mu g/m^3$, respectively The maximum FIRECONC concentration (3320 $\mu g/m^3$) was observed in an M60 at Fort Carson. These levels are all less than one third of the TLV (10,000 $\mu g/m^3$) for nuisance dust.

3.2.2.12 Sulfur Dioxide

Sulfur dioxide (SO_2) was detected only in the M109 and M3 and then in fewer than 50% of the samples (Appendix B). The concentrations observed during the firing period (FIRECONC) in the M109 ranged from below the detection limit (~100 $\mu g/m^3$) to 8400 $\mu g/m^3$ with most measurable values clustered around 200 $\mu g/m^3$. The concentrations observed over the total exercise period ranged from below the detection limit (~50 $\mu g/m^3$) to 4550 $\mu g/m^3$ with the measurable values clustered around 100 $\mu g/m^3$. The maximum FIRECONC concentration was 565 $\mu g/m^3$. All the SO_2 concentrations except the single measurement at 8400 $\mu g/m^3$ are less than one quarter of the TLV (5000 $\mu g/m^3$).

3.2.2.13 Aldehydes

A group of aldehydes was monitored in each vehicle type. These included: acetaldehyde, acrolein, crotonaldehyde, butyraldehyde, benzaldehyde, and hexanal. Few were detected at levels above the detection limit and, when found, they were observed most consistently in the tanks (Table 29). The mean acetaldehyde concentrations observed during the firing period (FIRECONC) ranged from below the detection limit (~1 $\mu g/m^3$) to 39.1 $\mu g/m^3$. The maximum FIRECONC concentration (424 $\mu g/m^3$) was observed in an M109 at Fort Sill. These levels are all significantly less than the TLV (180,000 $\mu g/m^3$). Other aldehydes were found less frequently and no concentrations exceeded 195 $\mu g/m^3$.

3.2.2.14 Polycyclic Aromatic Hydrocarbons

A group of polycyclic aromatic hydrocarbons (PAHs) were monitored in each vehicle type. The compounds included the following:

Naphthalene	Benz(a)anthracene
Acenaphthylene	Chrysene
Acenaphthene	Benzo(b)fluoranthene
Fluorene	Benzo(k)fluoranthene
Phenanthrene	Benzo(a)pyrene
Anthracene	Benzo(g,h,i)perylene
Fluoranthene	Dibenz(a,h)anthracene
Pyrene	Indeno(1,2,3-c,d)pyrene

Only three of these PAHs were found at a level above the detection limit (~1 $\mu g/m^3$). Specifically, naphthalene, acenaphthene and pyrene were occasionally found and then most frequently in the tanks (Table 30).

The mean concentration of naphthalene observed during the firing period (FIRECONC) ranged from below the detection limit to 6.9 $\mu g/m^3$. The maximum concentration (120 $\mu g/m^3$) was observed in an M60 at Fort Carson. These levels are all less than the TLV (50,000 $\mu g/m^3$). The other two PAHs were found less frequently and no concentrations exceeded 1700 $\mu g/m^3$.

3.2.2.15 Nitro-Polycyclic Aromatic Hydrocarbons

A group of polycyclic aromatic hydrocarbons containing one or more nitro groups (NO_2-PAHs) were monitored in each vehicle type. The compounds included the following:

1-Nitropyrene
2,7-Dinitrofluorene
1,8-Dinitropyrene
2-Nitronaphthalene
2-Nitrofluorene
3-Nitro-9-fluorenone
9-Nitroanthracene

None of these NO_2-PAHs were found at a level above the detection limit (~100 ng/m^3).

3.2.2.16 Metals

A group of metals was monitored in each vehicle type. These elements included those listed in Table 31. Ten of these metals were found consistently at a level above the detection limit. Specifically, these included those marked with an asterisk.

The mean concentration ranges of these metals observed during the firing period (FIRECONC) is reported in Table 32. The maximum concentration for each metal is also reported. These levels are all less than the respective TLVs. All concentrations for these metals are reported in Table 33.

3.2.2.17 Organic Vapors

Gas chromatography/mass spectrometry (GC/MS) was utilized to identify and quantify organic vapors which were present in armored vehicles. Several hundred peaks (compounds) were observed in a typical sample (Figure 32). Approximately 100 of the larger peaks were selected for identification and quantification in samples collected across all vehicle types (Table 34). These compounds are generally branched aliphatic and aromatic hydrocarbons. Few oxygenated species were observed although they may be present at lower concentrations.

Twelve compounds (Table 35) were selected for statistical analysis across vehicle types. They were chosen to represent the range of compound classes monitored. The range of mean concentrations and maximum concentration observed in all vehicles is reported in Table 35. It is apparent that most of the organic vapors identified in this program are found at concentration levels below 1000 $\mu g/m^3$.

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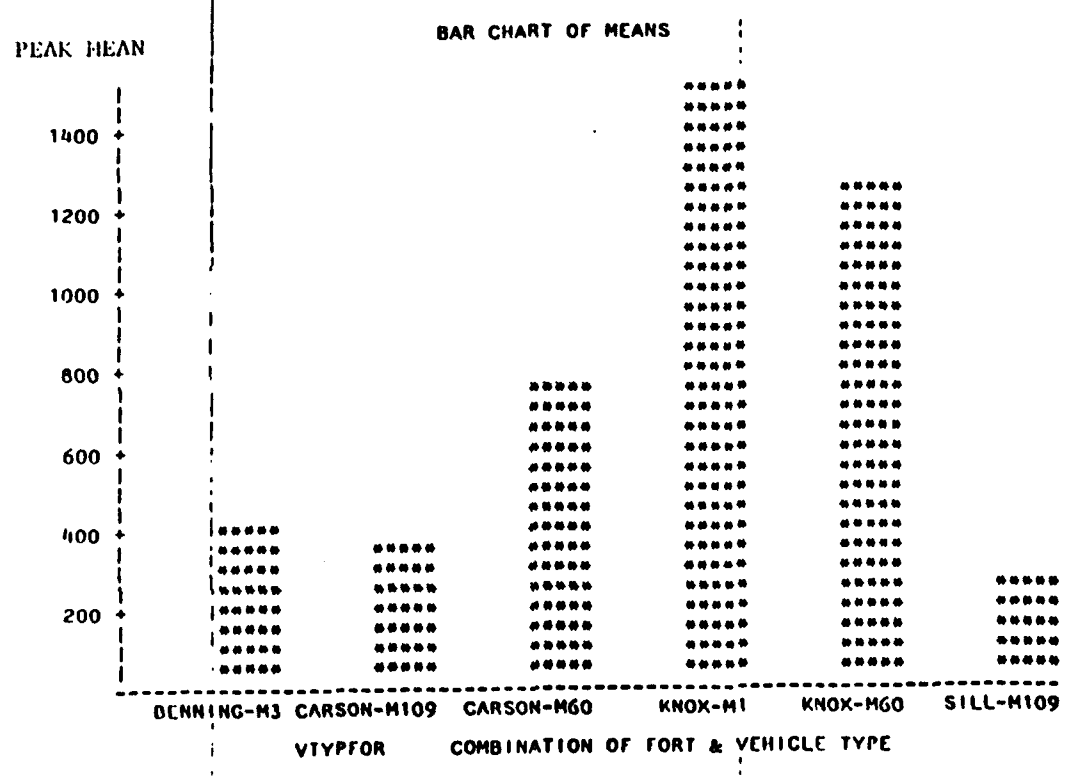


Figure 11. Concentration (peak) of carbon monoxide (ppm).

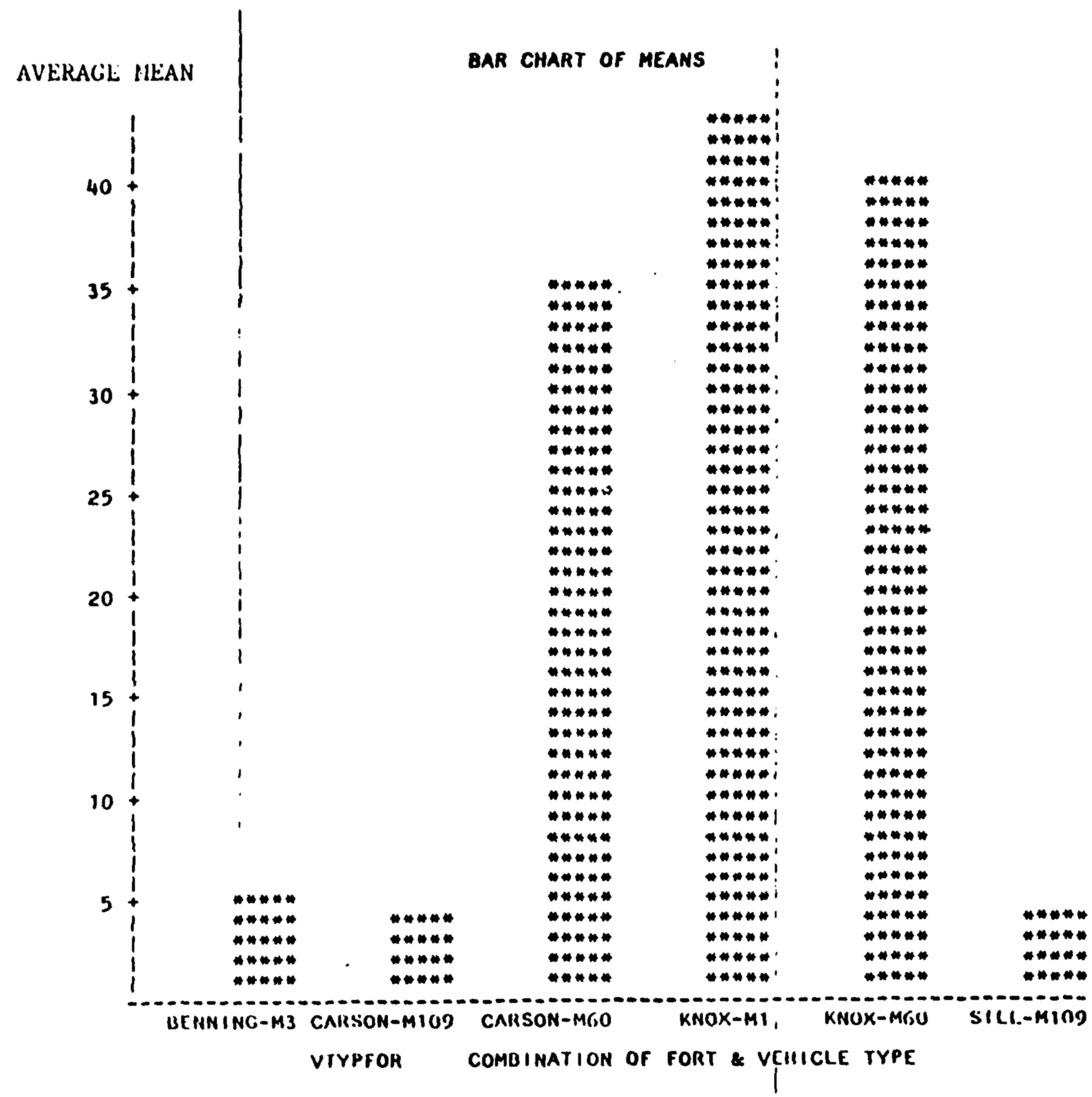


Figure 12. Concentration (average) of carbon monoxide (ppm).

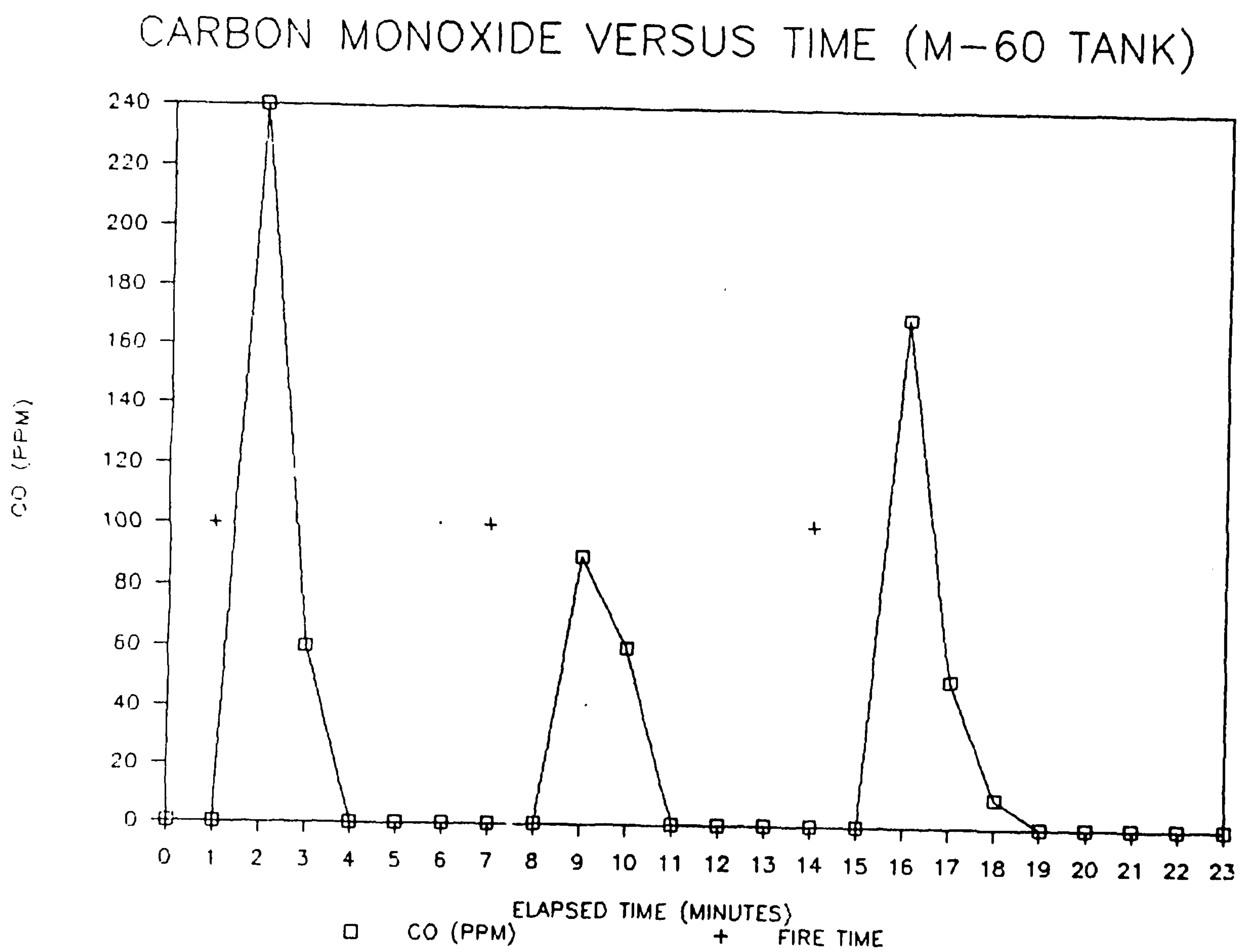


Figure 13. Carbon monoxide versus time (M60 tank).

TABLE 19. SUMMARY OF CARBON MONOXIDE CONCENTRATION DATA (ppm)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY														
COMMAND	1	10.0	18.0	4.0	16.0	10.0	10.0	7.0	70.0	9.0	71.0	5.0	60.0	45.0	71.0
	2	10.0	10.0	.	.	10.0	9.0	.	.	9.0	103.0	6.0	70.0	35.0	103.0
	3	6.0	8.0	.	.	.	.	.	.	.	.	.	.	6.0	8.0
	4	8.0	2.0	.	.	.	.	.	.	.	.	.	.	8.0	2.0
	ALL	34.0	18.0	4.0	16.0	20.0	10.0	7.0	70.0	18.0	103.0	11.0	70.0	94.0	103.0
DRIVER	DAY														
	1	8.0	13.0	3.0	4.0	9.0	13.0	7.0	50.0	9.0	113.0	6.0	40.0	42.0	113.0
	2	9.0	16.0	.	.	9.0	15.0	.	.	9.0	94.0	7.0	40.0	34.0	94.0
	3	5.0	6.0	.	.	.	.	.	.	.	.	.	.	5.0	6.0
	4	7.0	4.0	.	.	.	.	.	.	.	.	.	.	7.0	4.0
	ALL	29.0	16.0	3.0	4.0	18.0	15.0	7.0	50.0	18.0	113.0	13.0	40.0	88.0	113.0
GUNNER	DAY														
	1	.	.	.	.	.	.	4.0	70.0	3.0	83.0	4.0	70.0	11.0	83.0
	2	.	.	.	.	.	.	.	.	4.0	108.0	4.0	60.0	8.0	108.0
	ALL	.	.	.	.	.	.	4.0	70.0	7.0	108.0	8.0	70.0	19.0	108.0
LOADER	DAY														
	1	9.0	20.0	4.0	5.0	10.0	7.0	8.0	100.0	8.0	77.0	7.0	590.0	46.0	590.0
	2	9.0	8.0	.	.	10.0	11.0	.	.	8.0	80.0	8.0	50.0	35.0	80.0
	3	6.0	13.0	.	.	.	.	.	.	.	.	.	.	6.0	13.0
	4	7.0	2.0	.	.	.	.	.	.	.	.	.	.	7.0	2.0
	ALL	31.0	20.0	4.0	5.0	20.0	11.0	8.0	100.0	16.0	80.0	15.0	590.0	94.0	590.0

(CONTINUED)

TABLE 19 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY														
	1	27.0	20.0	11.0	16.0	29.0	13.0	26.0	100.0	29.0	113.0	22.0	590.0	144.0	590.0
	2	28.0	16.0	.	.	29.0	15.0	.	.	30.0	108.0	25.0	70.0	112.0	108.0
	3	17.0	13.0	.	.	.	.	.	.	.	.	.	.	17.0	13.0
	4	22.0	4.0	.	.	.	.	.	.	.	.	.	.	22.0	4.0
	ALL	94.0	20.0	11.0	16.0	58.0	15.0	26.0	100.0	59.0	113.0	47.0	590.0	295.0	590.0

TABLE 19 (continued)

ALL

		SILL-M109 TOTCONC MEAN	SILL-M109 TOTCONC STD	CARSON-M109 TOTCONC MEAN	CARSON-M109 TOTCONC STD	BENNING-M3 TOTCONC MEAN	BENNING-M3 TOTCONC STD	KNOX-M60 TOTCONC MEAN	KNOX-M60 TOTCONC STD	CARSON-M60 TOTCONC MEAN	CARSON-M60 TOTCONC STD	KNOX-M1 TOTCONC MEAN	KNOX-M1 TOTCONC STD	ALL TOTCONC MEAN	ALL TOTCONC STD
POSITION	DAY														
COMMAND	1	3.8	5.2	8.3	7.5	3.6	2.6	28.6	26.1	30.0	24.5	40.0	18.7	17.3	21.2
	2	5.4	2.7	.	.	5.9	2.1	.	.	33.8	34.8	31.7	25.6	17.3	23.9
	3	3.5	3.3	.	.	.	.	.	.	.	.	.	.	3.5	3.3
	4	0.9	0.8	.	.	.	.	.	.	.	.	.	.	0.9	0.8
	ALL	3.5	3.7	8.3	7.5	4.8	2.6	28.6	26.1	31.9	29.2	35.5	22.1	15.0	21.3
DRIVER	DAY														
	1	4.3	4.4	1.3	2.3	2.9	3.9	32.9	12.5	34.8	35.0	20.0	11.0	17.3	22.1
	2	6.1	4.5	.	.	6.7	4.4	.	.	38.4	39.7	14.3	15.1	16.5	24.9
	3	2.2	2.3	.	.	.	.	.	.	.	.	.	.	2.2	2.3
	4	1.9	1.6	.	.	.	.	.	.	.	.	.	.	1.9	1.6
	ALL	3.9	3.9	1.3	2.3	4.8	4.5	32.9	12.5	36.6	36.4	16.9	13.2	14.9	22.2
GUNNER	DAY														
	1	.	.	.	.	.	.	42.5	20.6	39.7	37.5	42.5	22.2	41.7	23.6
	2	.	.	.	.	.	.	.	.	46.3	44.1	25.0	26.5	35.6	35.6
	ALL	.	.	.	.	.	.	42.5	20.6	43.4	38.2	33.8	24.5	39.2	28.5
LOADER	DAY														
	1	4.7	6.0	2.3	2.6	2.5	1.8	56.3	32.0	36.3	24.8	130.0	205.1	37.5	88.7
	2	4.7	2.7	.	.	6.4	2.5	.	.	31.6	32.1	26.3	13.0	16.3	19.9
	3	3.2	4.9	.	.	.	.	.	.	.	.	.	.	3.2	4.9
	4	0.7	0.8	.	.	.	.	.	.	.	.	.	.	0.7	0.8
	ALL	3.5	4.3	2.3	2.6	4.4	2.9	56.3	32.0	33.9	27.8	74.7	144.9	24.7	64.3
ALL	DAY														
	1	4.2	5.1	4.2	5.5	3.0	2.8	40.4	26.0	34.2	28.0	63.6	120.1	25.6	53.9

(CONTINUED)

TABLE 19 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ALL	DAY														
	2	5.4	3.3	.	.	6.3	3.0	.	.	36.3	35.3	24.0	19.4	18.1	24.2
	3	3.0	3.5	.	.	.	.	.	.	.	.	.	.	3.0	3.5
	4	1.1	1.2	.	.	.	.	.	.	.	.	.	.	1.1	1.2
	ALL	3.6	3.9	4.2	5.5	4.7	3.3	40.4	26.0	35.3	31.7	42.6	84.7	19.6	41.1

TABLE 19 (continued)

ALL

POSITION	DAY	SILL-M109 FIRECONC # OF VEHS.	SILL-M109 FIRECONC MAX	CARSON-M109 FIRECONC # OF VEHS.	CARSON-M109 FIRECONC MAX	BENNING-M3 FIRECONC # OF VEHS.	BENNING-M3 FIRECONC MAX	KNOX-M60 FIRECONC # OF VEHS.	KNOX-M60 FIRECONC MAX	CARSON-M60 FIRECONC # OF VEHS.	CARSON-M60 FIRECONC MAX	KNOX-M1 FIRECONC # OF VEHS.	KNOX-M1 FIRECONC MAX	ALL FIRECONC # OF VEHS.	ALL FIRECONC MAX
COMMAND	1	10.0	2250.0	4.0	2280.0	10.0	960.0	7.0	2280.0	9.0	1110.0	5.0	2120.0	45.0	2280.0
	2	10.0	540.0	.	.	10.0	1290.0	.	.	9.0	2280.0	6.0	2280.0	35.0	2280.0
	3	6.0	360.0	.	.	.	.	.	.	.	.	.	.	6.0	360.0
	4	8.0	200.0	.	.	.	.	.	.	.	.	.	.	8.0	200.0
	ALL	34.0	2250.0	4.0	2280.0	20.0	1290.0	7.0	2280.0	18.0	2280.0	11.0	2280.0	94.0	2280.0
DRIVER	1	8.0	920.0	3.0	140.0	9.0	270.0	7.0	720.0	9.0	2260.0	6.0	1090.0	42.0	2260.0
	2	9.0	1280.0	.	.	9.0	590.0	.	.	9.0	630.0	7.0	1410.0	34.0	1410.0
	3	5.0	110.0	.	.	.	.	.	.	.	.	.	.	5.0	110.0
	4	7.0	640.0	.	.	.	.	.	.	.	.	.	.	7.0	640.0
	ALL	29.0	1280.0	3.0	140.0	18.0	590.0	7.0	720.0	18.0	2260.0	13.0	1410.0	88.0	2260.0
GUNNER	1	.	.	.	.	.	.	4.0	2060.0	3.0	1560.0	4.0	2290.0	11.0	2290.0
	2	.	.	.	.	.	.	.	.	4.0	1160.0	4.0	2310.0	8.0	2310.0
	ALL	.	.	.	.	.	.	4.0	2060.0	7.0	1560.0	8.0	2310.0	19.0	2310.0
LOADER	1	9.0	2270.0	4.0	340.0	10.0	620.0	8.0	2290.0	8.0	1090.0	7.0	2290.0	46.0	2290.0
	2	9.0	680.0	.	.	10.0	1020.0	.	.	8.0	2140.0	8.0	2300.0	35.0	2300.0
	3	6.0	330.0	.	.	.	.	.	.	.	.	.	.	6.0	330.0
	4	7.0	160.0	.	.	.	.	.	.	.	.	.	.	7.0	160.0
	ALL	31.0	2270.0	4.0	340.0	20.0	1020.0	8.0	2290.0	16.0	2140.0	15.0	2300.0	94.0	2300.0

Header note: the six fort/vehicle columns are grouped under "COMBINATION OF FORT & VEHICLE TYPE".

(CONTINULD)

TABLE 19 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY														
	1	27.0	2270.0	11.0	2280.0	29.0	960.0	26.0	2290.0	29.0	2260.0	22.0	2290.0	144.0	2290.0
	2	28.0	1280.0	.	.	29.0	1290.0	.	.	30.0	2280.0	25.0	2310.0	112.0	2310.0
	3	17.0	360.0	.	.	.	.	.	.	.	.	.	.	17.0	360.0
	4	22.0	640.0	.	.	.	.	.	.	.	.	.	.	22.0	640.0
	ALL	94.0	2270.0	11.0	2280.0	58.0	1290.0	26.0	2290.0	59.0	2280.0	47.0	2310.0	295.0	2310.0

TABLE 19 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
POSITION	DAY	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
COMMAND	1	346.0	678.3	732.5	1036.8	452.0	260.4	995.7	771.4	563.3	301.1	1750.0	570.2	704.4	702.9
	2	257.0	147.5	.	.	715.0	352.9	.	.	1196.7	691.1	1853.3	803.4	903.1	749.2
	3	131.7	113.7	.	.	.	.	.	.	.	.	.	.	131.7	113.7
	4	71.3	55.7	.	.	.	.	.	.	.	.	.	.	71.3	55.7
	ALL	217.4	382.1	732.5	1036.8	583.5	330.6	995.7	771.4	880.0	611.2	1806.4	675.0	688.0	714.2
DRIVER	DAY														
	1	352.5	297.8	60.0	70.0	151.1	82.7	488.6	167.3	795.6	864.8	708.3	333.2	456.9	499.0
	2	328.9	380.3	.	.	300.0	162.3	.	.	378.9	172.9	788.6	508.5	429.1	362.1
	3	80.0	21.2	.	.	.	.	.	.	.	.	.	.	80.0	21.2
	4	170.0	210.7	.	.	.	.	.	.	.	.	.	.	170.0	210.7
	ALL	254.1	291.3	60.0	70.0	225.6	146.6	488.6	167.3	587.2	641.8	751.5	421.0	401.9	426.9
GUNNER	DAY														
	1	.	.	.	.	.	.	1762.5	276.5	976.7	549.0	1627.5	585.5	1499.1	549.8
	2	.	.	.	.	.	.	.	.	887.5	214.7	1557.5	686.9	1222.5	591.8
	ALL	.	.	.	.	.	.	1762.5	276.5	925.7	354.7	1592.5	592.1	1382.6	569.1
LOADER	DAY														
	1	471.1	702.5	165.0	150.2	202.0	160.1	1923.8	597.4	583.8	284.8	2131.4	282.8	910.9	897.8
	2	290.0	198.1	.	.	498.0	285.7	.	.	826.3	571.4	1548.8	516.5	759.7	615.7
	3	108.3	114.1	.	.	.	.	.	.	.	.	.	.	108.3	114.1
	4	57.1	52.2	.	.	.	.	.	.	.	.	.	.	57.1	52.2
	ALL	254.8	415.4	165.0	150.2	350.0	271.8	1923.8	597.4	705.0	453.7	1820.7	508.1	739.8	777.8
ALL	DAY														
	1	389.6	581.8	342.7	653.9	272.4	223.6	1262.7	791.3	683.8	549.6	1565.0	696.9	758.9	758.6

TABLE 19 (continued)

ALL

		SILL-M109 FIRECONC MEAN	SILL-M109 FIRECONC STD	CARSON-M109 FIRECONC MEAN	CARSON-M109 FIRECONC STD	BENNING-M3 FIRECONC MEAN	BENNING-M3 FIRECONC STD	KNOX-M60 FIRECONC MEAN	KNOX-M60 FIRECONC STD	CARSON-M60 FIRECONC MEAN	CARSON-M60 FIRECONC STD	KNOX-M1 FIRECONC MEAN	KNOX-M1 FIRECONC STD	ALL FIRECONC MEAN	ALL FIRECONC STD
ALL	DAY														
	2	290.7	250.3	.	.	511.4	321.0	.	.	811.3	573.2	1410.4	712.5	737.2	635.6
	3	108.2	93.2	.	.	.	.	.	.	.	.	.	.	108.2	93.2
	4	98.2	130.6	.	.	.	.	.	.	.	.	.	.	98.2	130.6
	ALL	241.1	365.2	342.7	651.9	391.9	299.5	1262.7	791.3	748.6	560.6	1482.8	701.9	663.9	694.6

Column header: COMBINATION OF FORT & VEHICLE TYPE (all columns except ALL)

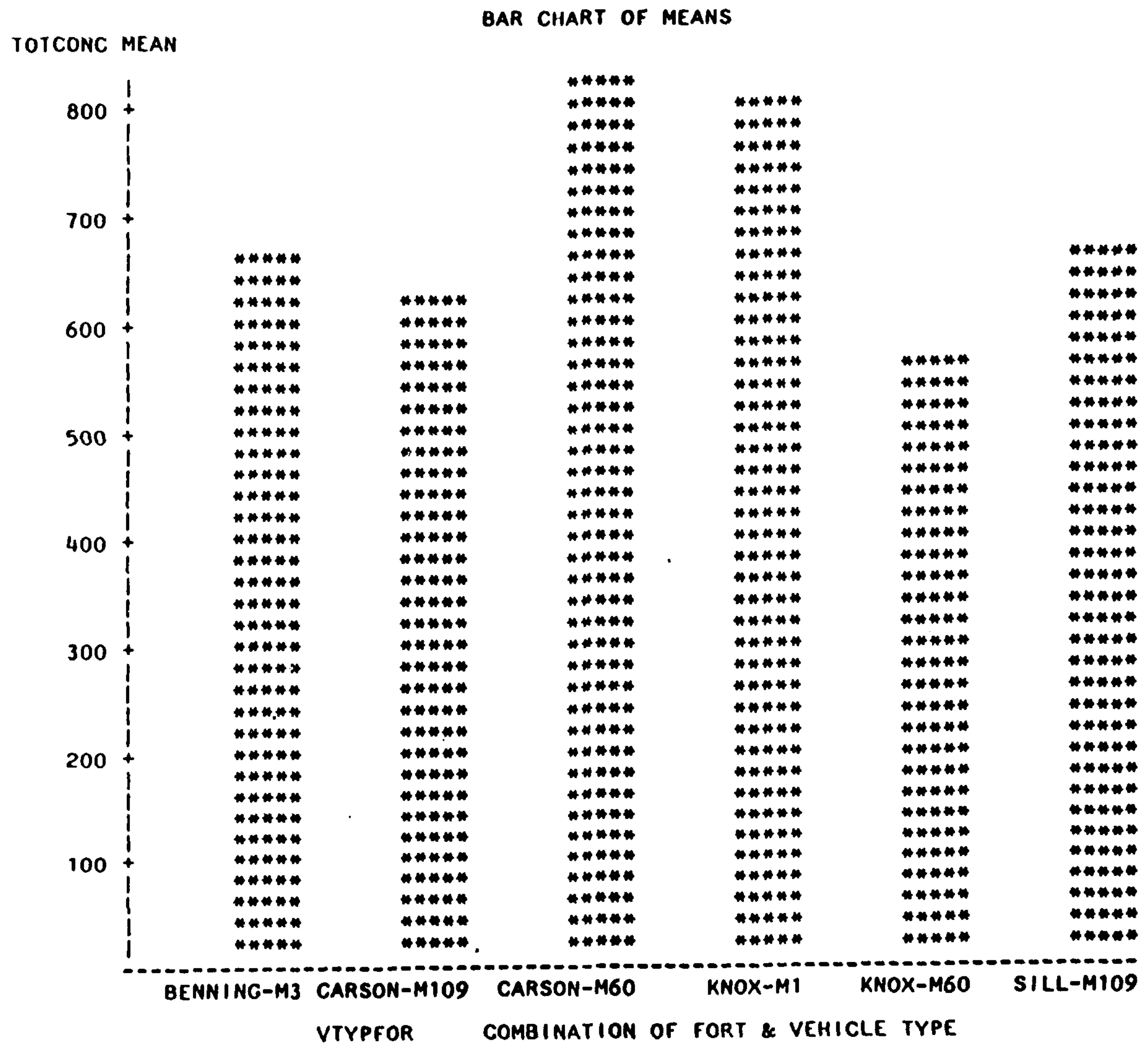


Figure 14. Concentration (TOTCONC) of carbon dioxide (ppm).

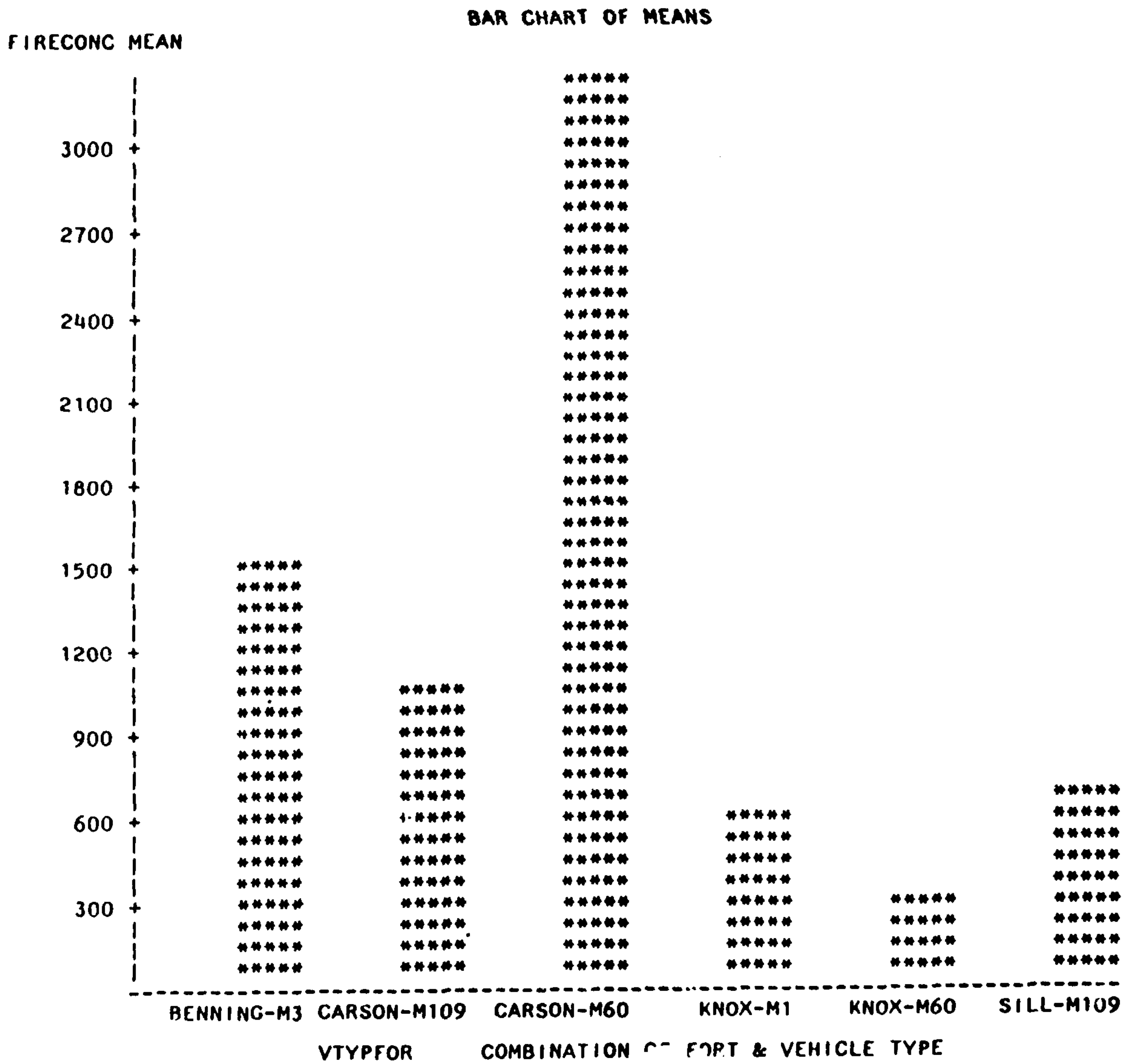


Figure 15. Concentration (FIRECONC) of carbon dioxide (ppm).

TABLE 20. SUMMARY OF CARBON DIOXIDE CONCENTRATION DATA (ppm)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY														
COMMAND	1	3.0	778.0	2.0	640.0	3.0	660.0	2.0	659.0	2.0	959.0	3.0	915.0	15.0	959.0
	2	2.0	694.0	.	.	1.0	658.0	.	.	2.0	769.0	2.0	832.0	7.0	832.0
	3	2.0	678.0	.	.	.	.	.	.	.	.	.	.	2.0	678.0
	4	2.0	1150.0	.	.	.	.	.	.	.	.	.	.	2.0	1150.0
	ALL	9.0	1150.0	2.0	640.0	4.0	660.0	2.0	659.0	4.0	959.0	5.0	915.0	26.0	1150.0
DRIVER	DAY														
	1	3.0	646.0	2.0	728.0	3.0	795.0	2.0	595.0	3.0	1100.0	2.0	1180.0	15.0	1180.0
	2	2.0	575.0	.	.	2.0	667.0	.	.	2.0	733.0	2.0	685.0	8.0	733.0
	3	1.0	583.0	.	.	.	.	.	.	.	.	.	.	1.0	583.0
	4	2.0	880.0	.	.	.	.	.	.	.	.	.	.	2.0	880.0
	ALL	8.0	880.0	2.0	728.0	5.0	795.0	2.0	595.0	5.0	1100.0	4.0	1180.0	26.0	1180.0
LOADER	DAY														
	1	3.0	675.0	2.0	673.0	2.0	751.0	2.0	575.0	3.0	1270.0	1.0	806.0	13.0	1270.0
	2	2.0	507.0	.	.	2.0	650.0	.	.	2.0	568.0	2.0	616.0	8.0	650.0
	3	1.0	589.0	.	.	.	.	.	.	.	.	.	.	1.0	589.0
	4	2.0	960.0	.	.	.	.	.	.	.	.	.	.	2.0	960.0
	ALL	8.0	960.0	2.0	673.0	4.0	751.0	2.0	575.0	5.0	1270.0	3.0	806.0	24.0	1270.0
ALL	DAY														
	1	9.0	778.0	6.0	728.0	8.0	795.0	6.0	659.0	8.0	1270.0	6.0	1180.0	43.0	1270.0
	2	6.0	694.0	.	.	5.0	667.0	.	.	6.0	769.0	6.0	832.0	23.0	832.0
	3	4.0	678.0	.	.	.	.	.	.	.	.	.	.	4.0	678.0
	4	6.0	1150.0	.	.	.	.	.	.	.	.	.	.	6.0	1150.0

(CONTINUED)

TABLE 20 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	25.0	1150.0	6.0	728.0	13.0	795.0	6.0	659.0	14.0	1270.0	12.0	1180.0	76.0	1270.0

TABLE 20 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY														
COMMAND	1	743.7	57.7	527.5	159.1	634.0	25.1	539.5	169.0	925.0	48.1	864.3	53.7	714.0	164.5
	2	558.0	192.3	.	.	658.0	.	.	.	642.0	179.6	716.0	164.0	641.4	142.3
	3	623.5	77.1	.	.	.	.	.	.	.	.	.	.	623.5	77.1
	4	906.0	345.1	.	.	.	.	.	.	.	.	.	.	906.0	345.1
	ALL	711.8	196.9	527.5	159.1	640.0	23.7	539.5	169.0	783.5	195.5	805.0	121.5	702.3	173.1
DRIVER	DAY														
	1	592.3	48.7	671.5	79.9	727.7	64.7	574.5	29.0	1005.3	83.0	1125.0	77.8	781.2	215.9
	2	565.5	13.4	.	.	626.5	57.3	.	.	691.5	58.7	665.5	27.6	637.3	60.6
	3	583.0	.	.	.	.	.	.	.	.	.	.	.	583.0	.
	4	779.0	142.8	.	.	.	.	.	.	.	.	.	.	779.0	142.8
	ALL	631.1	109.9	671.5	79.9	687.2	77.3	574.5	29.0	879.8	184.0	895.3	269.5	729.1	182.5
LOADER	DAY														
	1	653.7	29.5	644.0	41.0	725.0	36.8	555.0	28.3	987.7	294.1	806.0	.	736.8	199.3
	2	453.0	76.4	.	.	627.5	31.8	.	.	546.5	30.4	589.5	37.5	554.1	78.4
	3	589.0	.	.	.	.	.	.	.	.	.	.	.	589.0	.
	4	819.0	199.4	.	.	.	.	.	.	.	.	.	.	819.0	199.4
	ALL	636.8	162.3	644.0	41.0	676.3	62.9	555.0	28.3	811.2	319.2	661.7	127.8	676.6	183.5
ALL	DAY														
	1	663.2	77.4	614.3	106.5	691.9	62.2	556.3	79.3	978.6	167.9	941.5	151.9	744.3	191.7
	2	525.5	108.5	.	.	633.2	35.6	.	.	626.7	108.0	657.0	95.2	609.6	101.8
	3	604.8	49.5	.	.	.	.	.	.	.	.	.	.	604.8	49.5
	4	834.7	198.0	.	.	.	.	.	.	.	.	.	.	834.7	198.0
	ALL	[illegible]2.0	159.9	614.3	106.5	669.3	59.7	556.3	79.3	827.8	228.8	799.3	191.5	703.3	178.6

TABLE 20 (continued)

ALL

POSITION	DAY	SILL-M109 FIRECONC # OF VEHS.	SILL-M109 FIRECONC MAX	CARSON-M109 FIRECONC # OF VEHS.	CARSON-M109 FIRECONC MAX	BENNING-M3 FIRECONC # OF VEHS.	BENNING-M3 FIRECONC MAX	KNOX-M60 FIRECONC # OF VEHS.	KNOX-M60 FIRECONC MAX	CARSON-M60 FIRECONC # OF VEHS.	CARSON-M60 FIRECONC MAX	KNOX-M1 FIRECONC # OF VEHS.	KNOX-M1 FIRECONC MAX	ALL FIRECONC # OF VEHS.	ALL FIRECONC MAX
COMMAND	1	3.0	1240.0	2.0	1130.0	3.0	1640.0	2.0	402.0	2.0	3140.0	3.0	886.0	15.0	3140.0
	2	2.0	672.0	.	.	1.0	1580.0	.	.	2.0	5710.0	2.0	586.0	7.0	5710.0
	3	2.0	903.0	.	.	.	.	.	.	.	.	.	.	2.0	903.0
	4	2.0	1110.0	.	.	.	.	.	.	.	.	.	.	2.0	1110.0
	ALL	9.0	1240.0	2.0	1130.0	4.0	1640.0	2.0	402.0	4.0	5710.0	5.0	886.0	26.0	5710.0
DRIVER	1	3.0	890.0	2.0	1290.0	3.0	1860.0	2.0	326.0	3.0	3720.0	2.0	1120.0	15.0	3720.0
	2	2.0	424.0	.	.	2.0	1250.0	.	.	2.0	4150.0	2.0	420.0	8.0	4150.0
	3	1.0	658.0	.	.	.	.	.	.	.	.	.	.	1.0	658.0
	4	2.0	751.0	.	.	.	.	.	.	.	.	.	.	2.0	751.0
	ALL	8.0	890.0	2.0	1290.0	5.0	1860.0	2.0	326.0	5.0	4150.0	4.0	1120.0	26.0	4150.0
LOADER	1	3.0	976.0	2.0	1100.0	2.0	1840.0	2.0	317.0	3.0	3540.0	1.0	590.0	13.0	3540.0
	2	2.0	323.0	.	.	2.0	1550.0	.	.	2.0	3090.0	2.0	339.0	8.0	3090.0
	3	1.0	683.0	.	.	.	.	.	.	.	.	.	.	1.0	683.0
	4	2.0	848.0	.	.	.	.	.	.	.	.	.	.	2.0	848.0
	ALL	8.0	976.0	2.0	1100.0	4.0	1840.0	2.0	317.0	5.0	3540.0	3.0	590.0	24.0	3540.0
ALL	1	9.0	1240.0	6.0	1290.0	8.0	1860.0	6.0	402.0	8.0	3720.0	6.0	1120.0	43.0	3720.0
	2	6.0	672.0	.	.	5.0	1580.0	.	.	6.0	5710.0	6.0	586.0	23.0	5710.0
	3	4.0	903.0	.	.	.	.	.	.	.	.	.	.	4.0	903.0
	4	6.0	1110.0	.	.	.	.	.	.	.	.	.	.	6.0	1110.0

(CONTINUED)

TABLE 20 (continued)

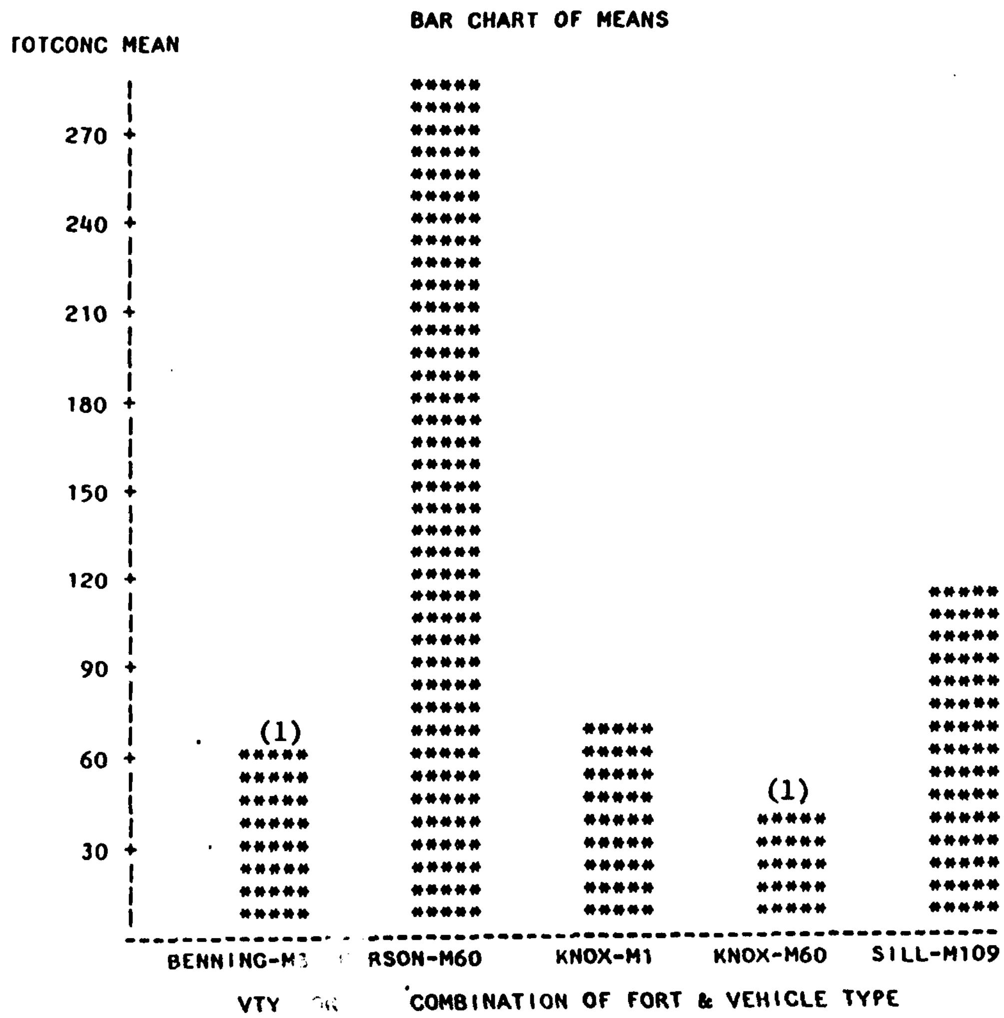
ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	25.0	1240.0	6.0	1290.0	13.0	1860.0	6.0	402.0	14.0	5710.0	12.0	1120.0	76.0	5710.0

TABLE 20 (continued)

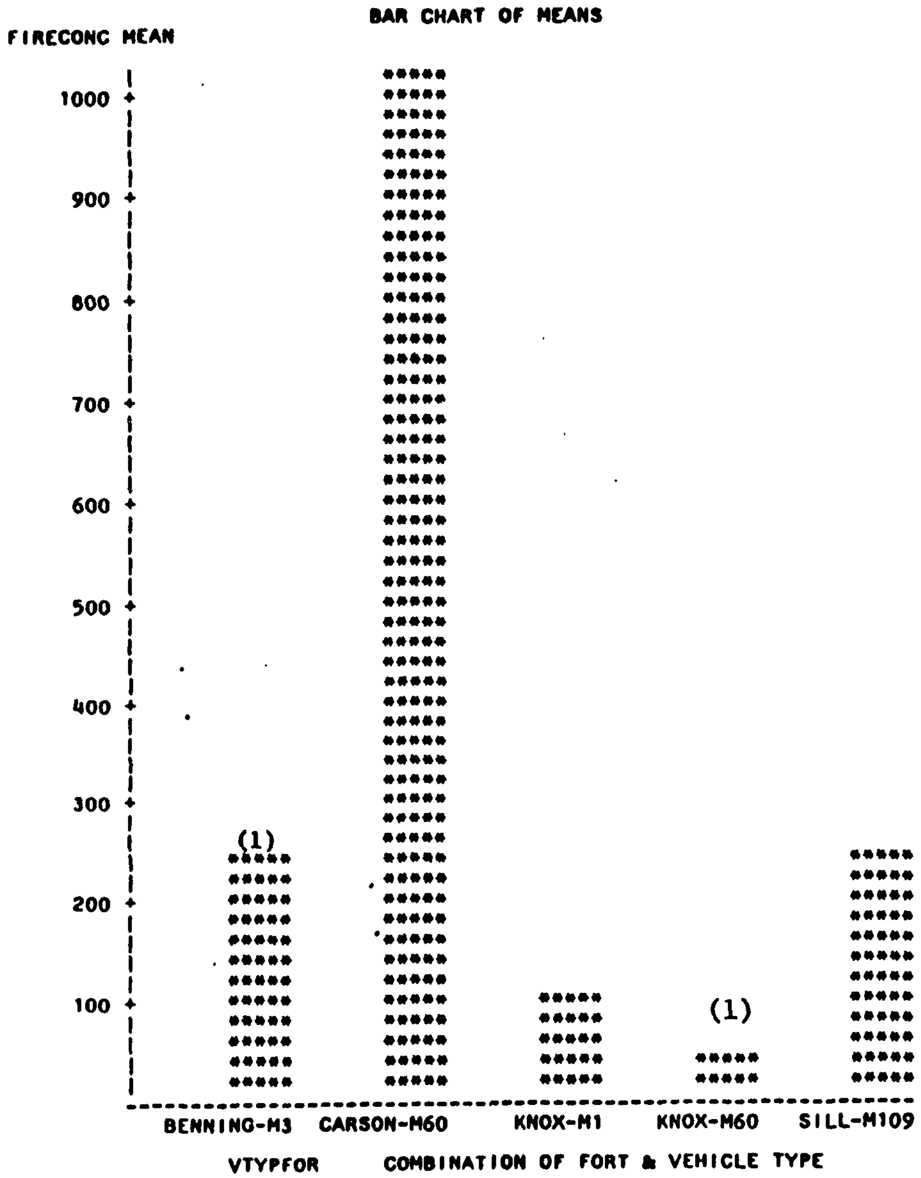
ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY														
COMMAND	1	1144.3	148.7	954.0	248.9	1373.3	260.3	259.0	202.2	3125.0	21.2	759.7	112.6	1233.9	856.7
	2	459.5	300.5	.	.	1580.0	.	.	.	3735.0	2793.1	453.0	188.1	1553.6	1926.2
	3	757.5	205.8	.	.	.	.	.	.	.	.	.	.	757.5	205.8
	4	819.5	410.8	.	.	.	.	.	.	.	.	.	.	819.5	410.8
	ALL	834.0	340.4	954.0	248.9	1425.0	236.3	259.0	202.2	3430.0	1650.6	637.0	208.3	1251.4	1170.5
DRIVER	DAY														
	1	728.0	148.3	1165.0	176.8	1763.3	95.0	307.5	26.2	3193.3	458.8	1085.0	49.5	1477.9	1018.4
	2	420.0	5.7	.	.	1245.0	7.1	.	.	3990.0	226.3	394.5	36.1	1512.4	1574.7
	3	658.0	.	.	.	.	.	.	.	.	.	.	.	658.0	.
	4	652.5	139.3	.	.	.	.	.	.	.	.	.	.	652.5	139.3
	ALL	623.4	161.2	1165.0	176.8	1556.0	291.8	307.5	26.2	3512.0	555.4	739.8	400.2	1393.5	1162.0
LOADER	DAY														
	1	902.7	86.7	1070.0	42.4	1760.0	113.1	283.0	48.1	2983.3	773.6	590.0	.	1421.1	1045.4
	2	260.5	88.4	.	.	1275.0	388.9	.	.	2475.0	869.7	305.5	47.4	1079.0	1030.2
	3	683.0	.	.	.	.	.	.	.	.	.	.	.	683.0	.
	4	701.0	207.9	.	.	.	.	.	.	.	.	.	.	701.0	207.9
	ALL	664.3	284.3	1070.0	42.4	1517.5	364.8	283.0	48.1	2780.0	752.2	400.3	167.6	1216.3	980.2
ALL	DAY														
	1	925.0	213.7	1063.0	167.1	1616.3	253.4	283.2	96.2	3097.5	490.9	839.8	214.3	1375.6	956.1
	2	380.0	168.9	.	.	1324.0	241.9	.	.	3400.0	1499.4	384.3	110.4	1374.2	1479.0
	3	714.0	129.4	.	.	.	.	.	.	.	.	.	.	714.0	129.4
	4	724.3	228.4	.	.	.	.	.	.	.	.	.	.	724.3	228.4
	ALL	712.3	280.6	1063.0	167.1	1503.8	280.8	283.2	96.2	3227.1	1009.2	612.1	288.1	1288.9	1098.8



(1) Most samples below the detection limit.

Figure 16. Concentration (TOTCONC) of hydrogen sulfide (ppb).



(1) Most samples below the detection limit.

Figure 17. Concentration (FIRECONC) of hydrogen sulfide (ppb).

TABLE 21. SUMMARY OF HYDROGEN SULFIDE CONCENTRATION DATA (ppb)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	4.0	86.1	4.0	56.6	4.0	52.5	4.0	146.0	4.0	151.0	20.0	151.0
	2	6.0	127.0	6.0	120.0	.	.	5.0	1880.0	4.0	76.2	21.0	1880.0
	3	4.0	143.0	.	.	.	.	.	.	.	.	4.0	143.0
	4	4.0	277.0	.	.	.	.	.	.	.	.	4.0	277.0
	ALL	18.0	277.0	10.0	120.0	4.0	52.5	9.0	1880.0	8.0	151.0	49.0	1880.0
DRIVER	DAY												
	1	4.0	114.0	4.0	95.6	4.0	36.5	4.0	102.0	4.0	75.4	20.0	114.0
	2	6.0	127.0	6.0	127.0	.	.	5.0	419.0	4.0	55.0	21.0	419.0
	3	4.0	279.0	.	.	.	.	.	.	.	.	4.0	279.0
	4	4.0	178.0	.	.	.	.	.	.	.	.	4.0	178.0
	ALL	18.0	279.0	10.0	127.0	4.0	36.5	9.0	419.0	8.0	75.4	49.0	419.0
GUNNER	DAY												
	1	.	.	.	.	2.0	72.0	2.0	111.0	2.0	75.4	6.0	111.0
	2	.	.	.	.	.	.	1.0	208.0	2.0	45.5	3.0	208.0
	ALL	.	.	.	.	2.0	72.0	3.0	208.0	4.0	75.4	9.0	208.0
LOADER	DAY												
	1	4.0	153.0	4.0	59.8	4.0	39.9	4.0	222.0	4.0	95.1	20.0	222.0
	2	4.0	117.0	6.0	122.0	.	.	5.0	892.0	4.0	248.0	19.0	892.0
	3	4.0	303.0	.	.	.	.	.	.	.	.	4.0	303.0
	4	4.0	412.0	.	.	.	.	.	.	.	.	4.0	412.0
	ALL	16.0	412.0	10.0	122.0	4.0	39.9	9.0	892.0	8.0	248.0	47.0	892.0

(CONTINUED)

TABLE 21 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY												
	1	12.0	153.0	12.0	95.6	14.0	72.0	14.0	222.0	14.0	151.0	66.0	222.0
	2	16.0	127.0	18.0	127.0	.	.	16.0	1880.0	14.0	248.0	64.0	1880.0
	3	12.0	303.0	.	.	.	.	.	.	.	.	12.0	303.0
	4	12.0	412.0	.	.	.	.	.	.	.	.	12.0	412.0
	ALL	52.0	412.0	30.0	127.0	14.0	72.0	30.0	1880.0	28.0	248.0	154.0	1880.0

TABLE 21 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
POSITION	DAY	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
COMMAND	1	69.8	16.6	49.6	6.7	38.5	9.9	95.2	51.4	100.0	44.9	70.6	37.7
	2	100.6	15.7	65.6	37.5	.	.	806.8	862.6	59.5	19.9	250.9	501.0
	3	80.2	45.8	.	.	.	.	.	.	.	.	80.2	45.8
	4	134.2	109.5	.	.	.	.	.	.	.	.	134.2	109.5
	ALL	96.7	56.3	59.2	29.4	38.5	9.9	490.5	716.7	79.7	38.7	153.9	336.9
DRIVER	DAY												
	1	91.2	16.0	64.5	24.1	31.5	5.1	74.2	28.3	66.0	10.5	65.5	26.0
	2	95.1	19.6	74.8	41.4	.	.	224.6	144.6	47.5	8.4	111.1	96.0
	3	133.4	98.0	.	.	.	.	.	.	.	.	133.4	98.0
	4	131.1	57.9	.	.	.	.	.	.	.	.	131.1	57.9
	ALL	110.7	53.3	70.7	34.2	31.5	5.1	157.7	130.5	56.8	13.2	95.9	75.0
GUNNER	DAY												
	1	.	.	.	.	47.3	34.9	83.3	39.1	70.2	7.3	67.0	28.7
	2	.	.	.	.	.	.	208.0	.	42.6	4.0	97.8	95.5
	ALL	.	.	.	.	47.3	34.9	124.9	77.1	56.4	16.6	77.2	55.1
LOADER	DAY												
	1	101.5	34.9	55.7	3.1	30.7	9.0	136.3	95.0	77.1	13.4	80.3	55.3
	2	95.6	18.3	63.9	37.8	.	.	378.8	319.7	91.7	104.4	159.3	208.1
	3	135.2	113.8	.	.	.	.	.	.	.	.	135.2	113.8
	4	166.7	171.3	.	.	.	.	.	.	.	.	166.7	171.3
	ALL	124.7	98.2	60.6	28.6	30.7	9.0	271.0	266.1	84.4	69.3	124.2	149.9
ALL	DAY												
	1	87.5	25.8	56.6	14.6	35.6	13.3	99.2	60.5	79.5	27.1	71.7	40.1

(CONTINUED)

TABLE 21 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ALL	DAY												
	2	97.3	16.9	68.1	36.9	.	.	453.7	544.3	62.9	54.9	170.6	314.5
	3	116.2	86.2	.	.	.	.	.	.	.	.	116.2	86.2
	4	144.0	111.7	.	.	.	.	.	.	.	.	144.0	111.7
	ALL	110.2	70.5	63.5	30.2	35.6	13.3	288.3	432.7	71.2	43.3	121.9	212.0

TABLE 21 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	4.0	259.0	4.0	291.0	4.0	67.0	4.0	701.0	4.0	226.0	20.0	701.0
	2	6.0	195.0	6.0	238.0	.	.	5.0	6120.0	4.0	108.0	21.0	6120.0
	3	4.0	301.0	.	.	.	.	.	.	.	.	4.0	301.0
	4	4.0	399.0	.	.	.	.	.	.	.	.	4.0	399.0
	ALL	18.0	399.0	10.0	291.0	4.0	67.0	9.0	6120.0	8.0	226.0	49.0	6120.0
DRIVER	DAY												
	1	4.0	362.0	4.0	430.0	4.0	44.7	4.0	540.0	4.0	113.0	20.0	540.0
	2	6.0	195.0	6.0	390.0	.	.	5.0	927.0	4.0	78.3	21.0	927.0
	3	4.0	608.0	.	.	.	.	.	.	.	.	4.0	608.0
	4	4.0	258.0	.	.	.	.	.	.	.	.	4.0	258.0
	ALL	18.0	608.0	10.0	430.0	4.0	44.7	9.0	927.0	8.0	113.0	49.0	927.0
GUNNER	DAY												
	1	.	.	.	.	2.0	88.8	2.0	579.0	2.0	113.0	6.0	579.0
	2	.	.	.	.	.	.	1.0	676.0	2.0	64.8	3.0	676.0
	ALL	.	.	.	.	2.0	88.8	3.0	676.0	4.0	113.0	9.0	676.0
LOADER	DAY												
	1	4.0	601.0	4.0	396.0	4.0	49.4	4.0	1090.0	4.0	131.0	20.0	1090.0
	2	4.0	204.0	6.0	252.0	.	.	5.0	2900.0	4.0	352.0	19.0	2900.0
	3	4.0	664.0	.	.	.	.	.	.	.	.	4.0	664.0
	4	4.0	599.0	.	.	.	.	.	.	.	.	4.0	599.0
	ALL	16.0	664.0	10.0	396.0	4.0	49.4	9.0	2900.0	8.0	352.0	47.0	2900.0

(CONTINUED)

TABLE 21 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY												
	1	12.0	601.0	12.0	430.0	14.0	88.8	14.0	1090.0	14.0	226.0	66.0	1090.0
	2	16.0	204.0	18.0	390.0	.	.	16.0	6120.0	14.0	352.0	64.0	6120.0
	3	12.0	664.0	.	.	.	.	.	.	.	.	12.0	664.0
	4	12.0	599.0	.	.	.	.	.	.	.	.	12.0	599.0
	ALL	52.0	664.0	30.0	430.0	14.0	88.8	30.0	6120.0	28.0	352.0	154.0	6120.0

TABLE 21 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CAPSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
POSITION	DAY	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
COMMAND	1	218.0	27.8	269.3	23.9	48.2	13.2	593.0	75.3	139.9	65.9	253.7	194.9
	2	179.7	12.5	192.8	28.9	.	.	2435.4	2346.[illegible]	84.2	28.0	702.3	1445.2
	3	206.6	98.9	.	.	.	.	.	.	.	.	206.6	98.9
	4	190.2	157.8	.	.	.	.	.	.	.	.	190.2	157.8
	ALL	196.5	80.9	223.[illegible]	47.0	48.2	13.2	1616.6	1923.0	112.0	55.5	436.9	970.5
DRIVER	DAY												
	1	292.3	72.9	321.3	88.7	39.6	6.2	494.0	45.3	93.1	21.9	248.0	176.0
	2	172.2	17.6	225.3	81.9	.	.	644.2	222.5	67.5	12.2	279.8	241.4
	3	329.0	188.3	.	.	.	.	.	.	.	.	329.0	188.3
	4	184.7	82.3	.	.	.	.	.	.	.	.	184.7	82.3
	ALL	236.5	115.4	263.7	93.8	39.6	6.2	577.4	178.3	80.3	21.4	263.1	200.6
GUNNER	DAY												
	1	.	.	.	.	58.5	42.9	545.0	48.1	96.6	23.2	233.4	243.9
	2	.	.	.	.	.	.	676.0	.	60.5	6.1	265.7	355.4
	ALL	.	.	.	.	58.5	42.9	588.7	82.9	78.5	25.0	244.1	262.7
LOADER	DAY												
	1	339.0	184.4	289.5	73.7	38.4	10.9	788.5	257.9	108.5	22.6	312.8	298.9
	2	178.8	24.2	186.8	35.8	.	.	1144.0	1015.2	130.1	148.2	425.1	654.6
	3	341.3	235.1	.	.	.	.	.	.	.	.	341.3	235.1
	4	238.4	250.4	.	.	.	.	.	.	.	.	238.4	250.4
	ALL	274.3	188.7	227.9	73.0	38.4	10.9	986.0	758.5	119.3	98.8	354.3	465.0
ALL	DAY												
	1	283.1	116.8	293.3	65.4	44.4	16.4	613.7	178.8	111.4	40.8	268.0	227.5

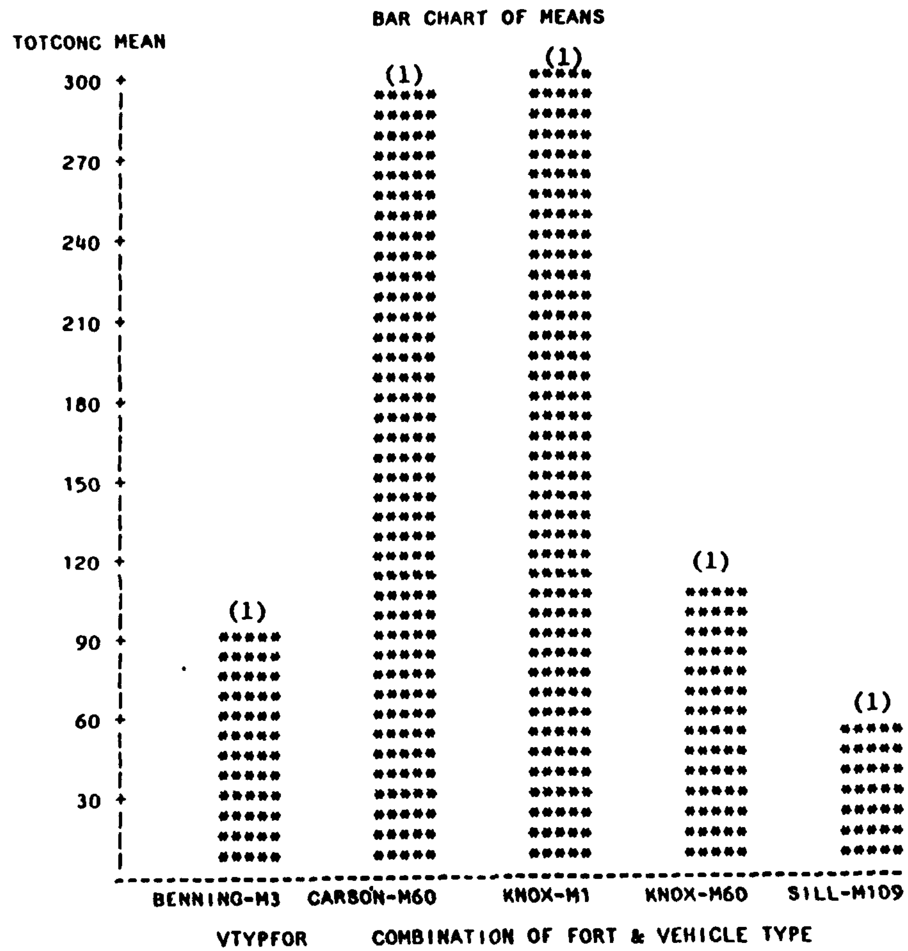
(CONTINUED)

TABLE 21 (continued)

ALL

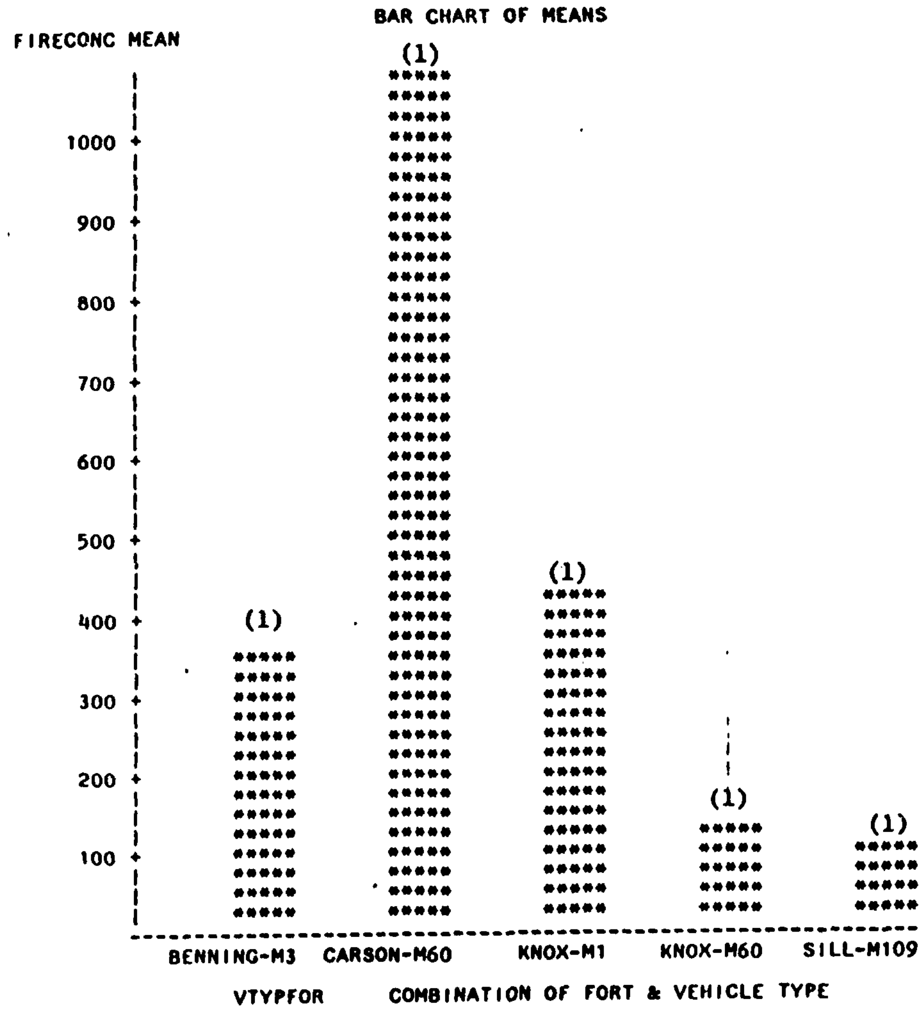
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1		ALL	
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ALL	DAY												
	2	176.6	16.9	201.7	53.8	.	.	1362.1	1536.0	89.1	78.0	460.9	916.8
	3	292.3	177.3	.	.	.	.	.	.	.	.	292.3	177.3
	4	204.4	162.4	.	.	.	.	.	.	.	.	204.4	162.4
	ALL	234.3	134.5	238.3	73.5	44.4	16.4	1012.9	1174.3	100.3	62.1	345.1	618.2

(Column group heading: COMBINATION OF FORT & VEHICLE TYPE)



(1) Most samples below the detection limit.

Figure 18. Concentration (TOTCONC) of hydrogen cyanide (ug/m^3).



(1) Most samples below the detection limit.

Figure 19. Concentration (FIRECONC) of hydrogen cyanide (ug/m^3).

TABLE 22. SUMMARY OF HYDROGEN CYANIDE CONCENTRATION DATA (ug/m^3)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
POSITION	DAY	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
COMMAND	1	2.0	32.3	2.0	79.9	2.0	177.0	2.0	223.0	2.0	208.0	10.0	223.0
	2	2.0	98.0	2.0	138.0	.	.	2.0	547.0	2.0	905.0	8.0	905.0
	3	2.0	30.0	.	.	.	.	.	.	.	.	2.0	30.0
	4	2.0	74.7	.	.	.	.	.	.	.	.	2.0	74.7
	ALL	8.0	98.0	4.0	138.0	2.0	177.0	4.0	547.0	4.0	905.0	22.0	905.0
DRIVER	DAY												
	1	2.0	45.4	2.0	88.8	2.0	80.6	2.0	230.0	2.0	208.0	10.0	230.0
	2	2.0	95.0	2.0	129.0	.	.	2.0	583.0	2.0	650.0	8.0	650.0
	3	2.0	37.4	.	.	.	.	.	.	.	.	2.0	37.4
	4	2.0	65.8	.	.	.	.	.	.	.	.	2.0	65.8
	ALL	8.0	95.0	4.0	129.0	2.0	80.6	4.0	583.0	4.0	650.0	22.0	650.0
LOADER	DAY												
	1	2.0	18.5	2.0	88.3	2.0	142.0	2.0	234.0	2.0	208.0	10.0	234.0
	2	2.0	111.0	2.0	153.0	.	.	2.0	476.0	2.0	152.0	8.0	476.0
	3	2.0	29.8	.	.	.	.	.	.	.	.	2.0	29.8
	4	2.0	74.3	.	.	.	.	.	.	.	.	2.0	74.3
	ALL	8.0	111.0	4.0	153.0	2.0	142.0	4.0	476.0	4.0	208.0	22.0	476.0
ALL	DAY												
	1	6.0	45.4	6.0	88.8	6.0	177.0	6.0	234.0	6.0	208.0	30.0	234.0
	2	6.0	111.0	6.0	153.0	.	.	6.0	583.0	6.0	905.0	24.0	905.0
	3	6.0	37.4	.	.	.	.	.	.	.	.	6.0	37.4
	4	6.0	74.7	.	.	.	.	.	.	.	.	6.0	74.7

(CONTINUED)

TABLE 22 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE											
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1		ALL	
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	24.0	111.0	12.0	153.0	6.0	177.0	12.0	583.0	12.0	905.0	66.0	905.0

TABLE 22 (continued)

ALL

		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1		ALL	
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
POSITION	DAY	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
COMMAND	1	25.4	9.8	65.7	20.1	136.8	56.8	163.0	84.9	179.5	40.3	114.1	72.5
	2	80.4	24.9	109.3	40.6	.	.	381.5	234.1	609.5	417.9	295.2	294.1
	3	29.3	1.1	.	.	.	.	.	.	.	.	29.3	1.1
	4	64.6	14.3	.	.	.	.	.	.	.	.	64.6	14.3
	ALL	49.9	27.4	87.5	36.3	136.8	56.8	272.3	191.2	394.5	347.0	167.7	203.7
DRIVER	1	31.9	19.0	71.9	23.8	79.8	1.1	166.5	89.8	179.5	40.3	105.9	69.4
	2	76.0	26.8	103.9	35.5	.	.	469.0	161.2	535.0	162.6	296.0	238.8
	3	31.3	8.6	.	.	.	.	.	.	.	.	31.3	8.6
	4	61.0	6.7	.	.	.	.	.	.	.	.	61.0	6.7
	ALL	50.1	24.3	87.9	30.8	79.8	1.1	317.8	204.6	357.3	226.9	164.2	178.9
LOADER	1	18.0	0.7	74.0	20.2	107.3	49.1	172.0	87.7	179.5	40.3	110.1	73.8
	2	85.4	36.2	124.9	39.7	.	.	403.0	103.2	127.5	34.6	185.2	143.2
	3	29.3	0.7	.	.	.	.	.	.	.	.	29.3	0.7
	4	65.6	12.3	.	.	.	.	.	.	.	.	65.6	12.3
	ALL	49.6	32.4	99.5	39.1	107.3	49.1	287.5	154.6	153.5	42.9	126.0	108.9
ALL	1	25.1	11.4	70.5	17.1	108.0	42.2	167.2	67.9	179.5	31.2	110.1	69.5
	2	80.6	23.4	112.7	31.5	.	.	417.8	141.2	424.0	307.1	258.8	229.7
	3	30.0	4.0	.	.	.	.	.	.	.	.	30.0	4.0
	4	63.7	9.2	.	.	.	.	.	.	.	.	63.7	9.2
	ALL	49.9	27.0	91.6	32.7	108.0	42.2	292.5	168.2	301.8	244.2	152.7	167.2

TABLE 22 (continued)

ALL

POSITION	DAY	SILL-M109 FIRECONC # OF VEHS.	SILL-M109 FIRECONC MAX	BENNING-M3 FIRECONC # OF VEHS.	BENNING-M3 FIRECONC MAX	KNOX-M60 FIRECONC # OF VEHS.	KNOX-M60 FIRECONC MAX	CARSON-M60 FIRECONC # OF VEHS.	CARSON-M60 FIRECONC MAX	KNOX-M1 FIRECONC # OF VEHS.	KNOX-M1 FIRECONC MAX	ALL FIRECONC # OF VEHS.	ALL FIRECONC MAX
COMMAND	1	2.0	142.0	2.0	360.0	2.0	226.0	2.0	1120.0	2.0	311.0	10.0	1120.0
	2	2.0	190.0	2.0	411.0	.	.	2.0	1090.0	2.0	1280.0	8.0	1280.0
	3	2.0	96.6	.	.	.	.	.	.	.	.	2.0	96.6
	4	2.0	108.0	.	.	.	.	.	.	.	.	2.0	108.0
	ALL	8.0	190.0	4.0	411.0	2.0	226.0	4.0	1120.0	4.0	1280.0	22.0	1280.0
DRIVER	1	2.0	193.0	2.0	400.0	2.0	102.0	2.0	1110.0	2.0	311.0	10.0	1110.0
	2	2.0	187.0	2.0	402.0	.	.	2.0	1170.0	2.0	919.0	8.0	1170.0
	3	2.0	122.0	.	.	.	.	.	.	.	.	2.0	122.0
	4	2.0	90.9	.	.	.	.	.	.	.	.	2.0	90.9
	ALL	8.0	193.0	4.0	402.0	2.0	102.0	4.0	1170.0	4.0	919.0	22.0	1170.0
LOADER	1	2.0	73.2	2.0	398.0	2.0	177.0	2.0	1190.0	2.0	311.0	10.0	1190.0
	2	2.0	182.0	2.0	494.0	.	.	2.0	1070.0	2.0	216.0	8.0	1070.0
	3	2.0	94.7	.	.	.	.	.	.	.	.	2.0	94.7
	4	2.0	108.0	.	.	.	.	.	.	.	.	2.0	108.0
	ALL	8.0	182.0	4.0	494.0	2.0	177.0	4.0	1190.0	4.0	311.0	22.0	1190.0
ALL	1	6.0	193.0	6.0	400.0	6.0	226.0	6.0	1190.0	6.0	311.0	30.0	1190.0
	2	6.0	190.0	6.0	494.0	.	.	6.0	1170.0	6.0	1280.0	24.0	1280.0
	3	6.0	122.0	.	.	.	.	.	.	.	.	6.0	122.0
	4	6.0	108.0	.	.	.	.	.	.	.	.	6.0	108.0

(CONTINUED)

TABLE 22 (continued)

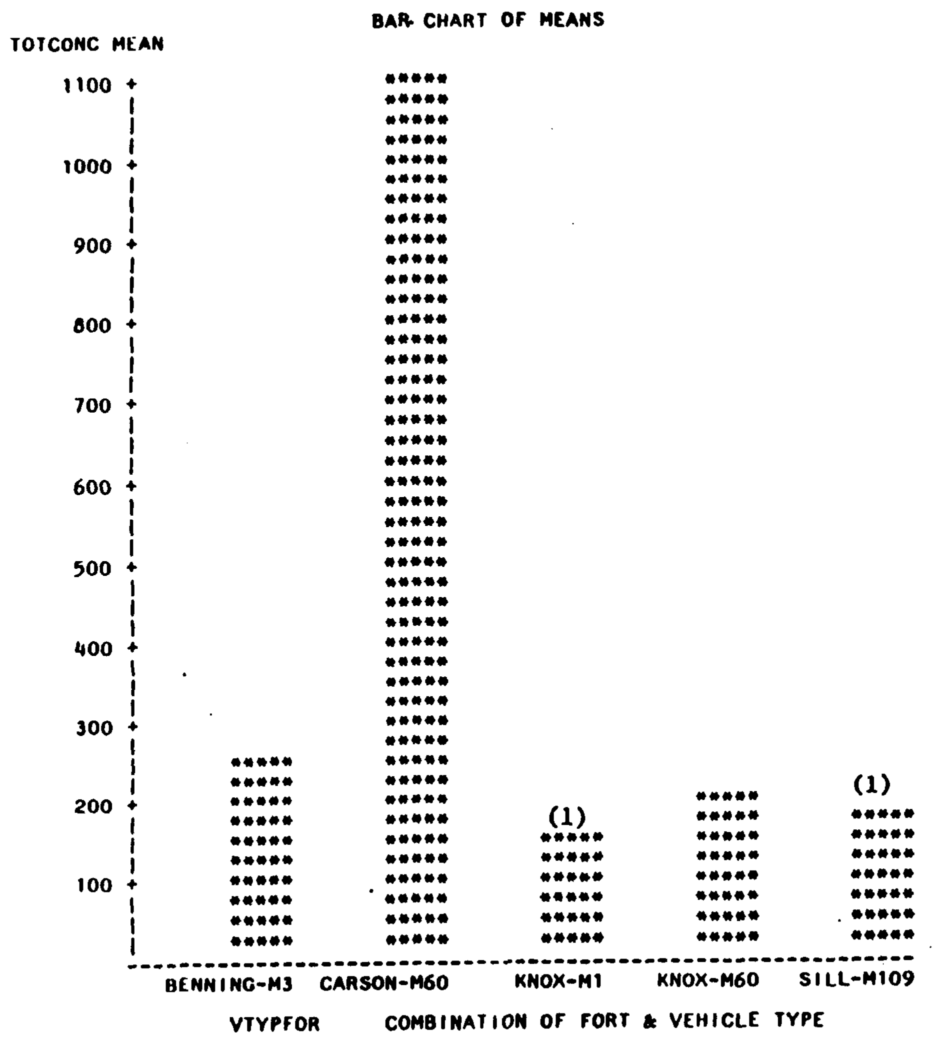
ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	24.0	193.0	12.0	494.0	6.0	226.0	12.0	1190.0	12.0	1280.0	66.0	1280.0

TABLE 22 (continued)

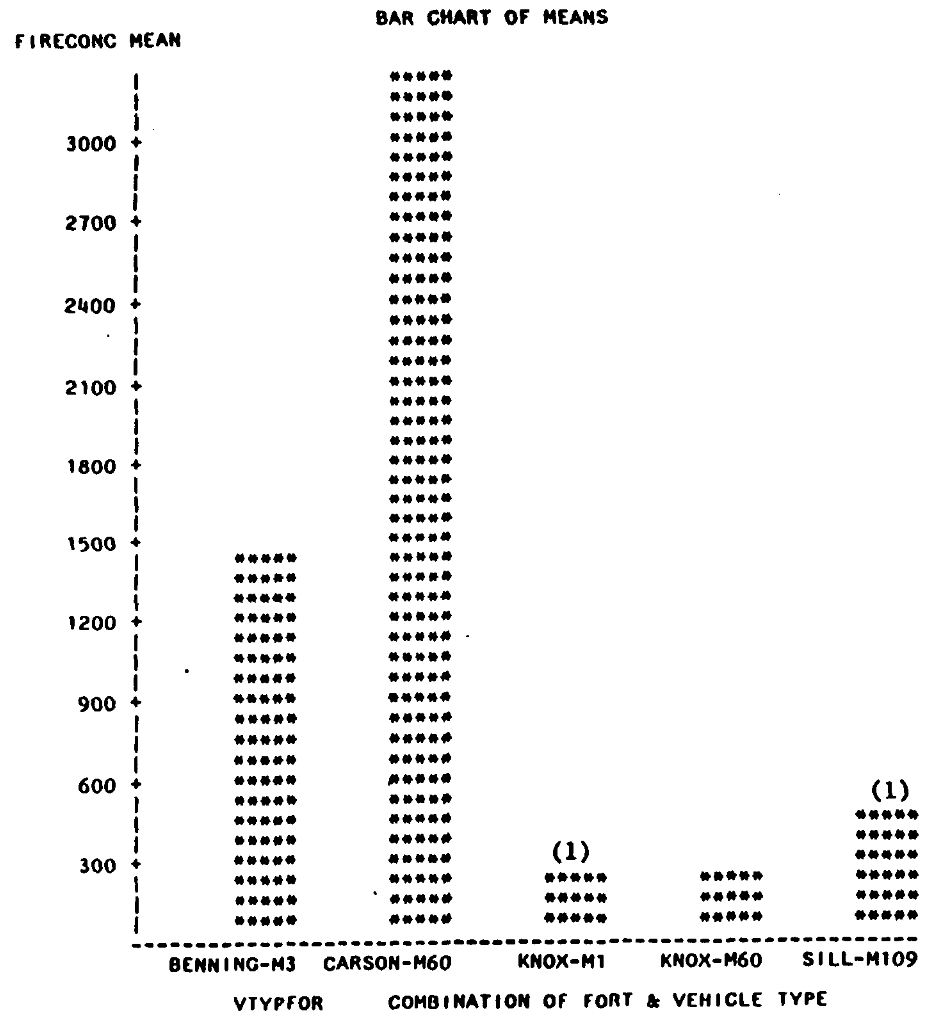
ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY												
COMMAND	1	93.3	68.9	349.5	14.8	174.5	72.8	1095.0	35.4	259.0	73.5	394.3	382.6
	2	151.0	55.2	309.5	143.5	.	.	895.5	275.1	864.0	588.3	555.0	433.5
	3	92.8	5.3	.	.	.	.	.	.	.	.	92.8	5.3
	4	91.6	23.2	.	.	.	.	.	.	.	.	91.6	23.2
	ALL	107.2	43.9	329.5	86.5	174.5	72.8	995.3	197.2	561.5	489.1	397.8	390.6
DRIVER	DAY												
	1	118.8	105.0	382.5	24.7	102.0	0.0	1095.0	21.2	259.0	73.5	391.4	388.6
	2	149.5	53.0	297.5	147.8	.	.	1160.0	14.1	759.0	226.3	591.5	437.9
	3	102.3	27.9	.	.	.	.	.	.	.	.	102.3	27.9
	4	86.2	6.6	.	.	.	.	.	.	.	.	86.2	6.6
	ALL	114.2	52.1	340.0	99.5	102.0	0.0	1127.5	40.3	509.0	319.7	410.2	400.5
LOADER	DAY												
	1	58.8	20.3	397.0	1.4	134.8	59.8	1170.0	28.3	259.0	73.5	403.9	422.8
	2	147.0	49.5	361.5	187.4	.	.	1010.5	84.1	181.0	49.5	425.0	380.7
	3	93.7	1.3	.	.	.	.	.	.	.	.	93.7	1.3
	4	93.3	20.8	.	.	.	.	.	.	.	.	93.3	20.8
	ALL	98.2	40.1	379.3	110.1	134.8	59.8	1090.3	105.4	220.0	68.2	355.1	375.5
ALL	DAY												
	1	90.3	62.9	376.3	25.3	137.1	53.2	1120.0	44.7	259.0	57.0	396.5	384.5
	2	149.2	40.8	322.8	128.2	.	.	1022.0	175.1	601.3	433.8	523.8	406.2
	3	96.3	13.5	.	.	.	.	.	.	.	.	96.3	13.5
	4	90.4	14.6	.	.	.	.	.	.	.	.	90.4	14.6
	ALL	106.5	44.1	349.6	92.4	137.1	53.2	1071.0	132.2	430.2	344.9	387.7	383.7



(1) Most samples below the detection limit.

Figure 20. Concentration (TOTCONC) of nitric oxide (ug/m^3).



(1) Most samples below the detection limit.

Figure 21. Concentration (FIRECONC) of nitric oxide (ug/m^3).

TABLE 23. SUMMARY OF NITRIC OXIDE CONCENTRATION DATA (ug/m^3)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
POSITION	DAY	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
COMMAND	1	1.0	209.0	2.0	563.0	2.0	199.0	2.0	609.0	2.0	245.0	9.0	609.0
	2	3.0	357.0	2.0	142.0	.	.	2.0	3210.0	2.0	244.0	9.0	3210.0
	3	2.0	261.0	.	.	.	.	.	.	.	.	2.0	261.0
	4	2.0	145.0	.	.	.	.	.	.	.	.	2.0	145.0
	ALL	8.0	357.0	4.0	563.0	2.0	199.0	4.0	3210.0	4.0	245.0	22.0	3210.0
DRIVER	DAY												
	1	2.0	189.0	2.0	280.0	2.0	176.0	2.0	671.0	2.0	235.0	10.0	671.0
	2	3.0	320.0	2.0	145.0	.	.	2.0	2060.0	2.0	161.0	9.0	2060.0
	3	2.0	41.8	.	.	.	.	.	.	.	.	2.0	41.8
	4	2.0	197.0	.	.	.	.	.	.	.	.	2.0	197.0
	ALL	9.0	320.0	4.0	280.0	2.0	176.0	4.0	2060.0	4.0	235.0	23.0	2060.0
LOADER	DAY												
	1	2.0	283.0	2.0	404.0	2.0	250.0	2.0	483.0	2.0	245.0	10.0	483.0
	2	2.0	339.0	1.0	182.0	.	.	2.0	2720.0	3.0	121.0	8.0	2720.0
	3	2.0	144.0	.	.	.	.	.	.	.	.	2.0	144.0
	4	2.0	187.0	.	.	.	.	.	.	.	.	2.0	187.0
	ALL	8.0	339.0	3.0	404.0	2.0	250.0	4.0	2720.0	5.0	245.0	22.0	2720.0
ALL	DAY												
	1	5.0	283.0	6.0	563.0	6.0	250.0	6.0	671.0	6.0	245.0	29.0	671.0
	2	8.0	357.0	5.0	182.0	.	.	6.0	3210.0	7.0	244.0	26.0	3210.0
	3	6.0	261.0	.	.	.	.	.	.	.	.	6.0	261.0
	4	6.0	197.0	.	.	.	.	.	.	.	.	6.0	197.0

(CONTINUED)

TABLE 23 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	25.0	357.0	11.0	563.0	6.0	250.0	12.0	3210.0	13.0	245.0	67.0	3210.0

TABLE 23 (continued)

ALL

		SILL-M109 TOTCONC MEAN	SILL-M109 TOTCONC STD	BENNING-M3 TOTCONC MEAN	BENNING-M3 TOTCONC STD	KNOX-M60 TOTCONC MEAN	KNOX-M60 TOTCONC STD	CARSON-M60 TOTCONC MEAN	CARSON-M60 TOTCONC STD	KNOX-M1 TOTCONC MEAN	KNOX-M1 TOTCONC STD	ALL TOTCONC MEAN	ALL TOTCONC STD
POSITION	DAY												
COMMAND	1	209.0	.	482.5	113.8	194.0	7.1	397.0	299.8	186.0	83.4	303.1	177.5
	2	331.7	27.2	128.0	19.8	.	.	2080.0	1598.1	168.5	106.7	638.7	998.0
	3	156.6	147.6	.	.	.	.	.	.	.	.	156.6	147.6
	4	111.1	47.9	.	.	.	.	.	.	.	.	111.1	47.9
	ALL	217.4	116.4	305.3	215.3	194.0	7.1	1238.5	1351.1	177.3	78.8	409.6	659.2
DRIVER	DAY												
	1	139.5	70.0	240.0	56.6	168.5	10.6	416.5	359.9	176.5	82.7	228.2	164.7
	2	285.7	36.1	120.5	34.6	.	.	1710.0	495.0	118.3	60.3	528.3	697.4
	3	38.9	4.0	.	.	.	.	.	.	.	.	38.9	4.0
	4	129.2	95.9	.	.	.	.	.	.	.	.	129.2	95.9
	ALL	163.6	109.6	180.3	78.9	168.5	10.6	1063.3	826.2	147.4	68.0	320.6	469.5
LOADER	DAY												
	1	198.0	120.2	331.0	103.2	222.0	39.6	312.5	241.1	208.0	52.3	254.3	114.9
	2	298.5	57.3	182.0	.	.	.	1648 5	1515.3	109.7	10.3	550.6	891.0
	3	101.3	60.5	.	.	.	.	.	.	.	.	101.3	60.5
	4	125.5	86.9	.	.	.	.	.	.	.	.	125.5	86.9
	ALL	180.8	104.2	281.3	112.8	222.0	39.6	980.5	1174.6	149.0	60.3	336.4	548.6
ALL	DAY												
	1	176.8	77.6	351.2	131.8	194.8	30.3	375.3	240.7	190.2	59.3	260.4	151.4
	2	306.1	39.1	135.8	32.8	.	.	1812.8	1030.8	129.0	57.3	573.4	836.1
	3	98.9	88.7	.	.	.	.	.	.	.	.	98.9	88.7
	4	121.9	62.3	.	.	.		.	.	.	.	121.9	62.3
	ALL	186.3	107.9	253.3	147.5	194.8	30.3	094.1	1035.8	157.2	64.2	355.0	555.9

TABLE 23 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	1.0	920.0	2.0	3700.0	2.0	254.0	2.0	2920.0	2.0	366.0	9.0	3700.0
	2	3.0	667.0	2.0	662.0	.	.	2.0	6430.0	2.0	347.0	9.0	6430.0
	3	2.0	838.0	.	.	.	.	.	.	.	.	2.0	838.0
	4	2.0	210.0	.	.	.	.	.	.	.	.	2.0	210.0
	ALL	8.0	920.0	4.0	3700.0	2.0	254.0	4.0	6430.0	4.0	366.0	22.0	6430.0
DRIVER	DAY												
	1	2.0	802.0	2.0	1850.0	2.0	222.0	2.0	3150.0	2.0	352.0	10.0	3150.0
	2	3.0	630.0	2.0	676.0	.	.	2.0	4410.0	2.0	229.0	9.0	4410.0
	3	2.0	135.0	.	.	.	.	.	.	.	.	2.0	135.0
	4	2.0	286.0	.	.	.	.	.	.	.	.	2.0	286.0
	ALL	9.0	802.0	4.0	1850.0	2.0	222.0	4.0	4410.0	4.0	352.0	23.0	4410.0
LOADER	DAY												
	1	2.0	1180.0	2.0	2680.0	2.0	312.0	2.0	2370.0	2.0	366.0	10.0	2680.0
	2	2.0	635.0	1.0	851.0	.	.	2.0	5440.0	3.0	172.0	8.0	5440.0
	3	2.0	473.0	.	.	.	.	.	.	.	.	2.0	473.0
	4	2.0	273.0	.	.	.	.	.	.	.	.	2.0	273.0
	ALL	8.0	1180.0	3.0	2680.0	2.0	312.0	4.0	5440.0	5.0	366.0	22.0	5440.0
ALL	DAY												
	1	5.0	1180.0	6.0	3700.0	6.0	312.0	6.0	3150.0	6.0	366.0	29.0	3700.0
	2	8.0	667.0	5.0	851.0	.	.	6.0	6430.0	7.0	347.0	26.0	6430.0
	3	6.0	838.0	.	.	.	.	.	.	.	.	6.0	838.0
	4	6.0	286.0	.	.	.	.	.	.	.	.	6.0	286.0

(CONTINUED)

TABLE 23 (continued)

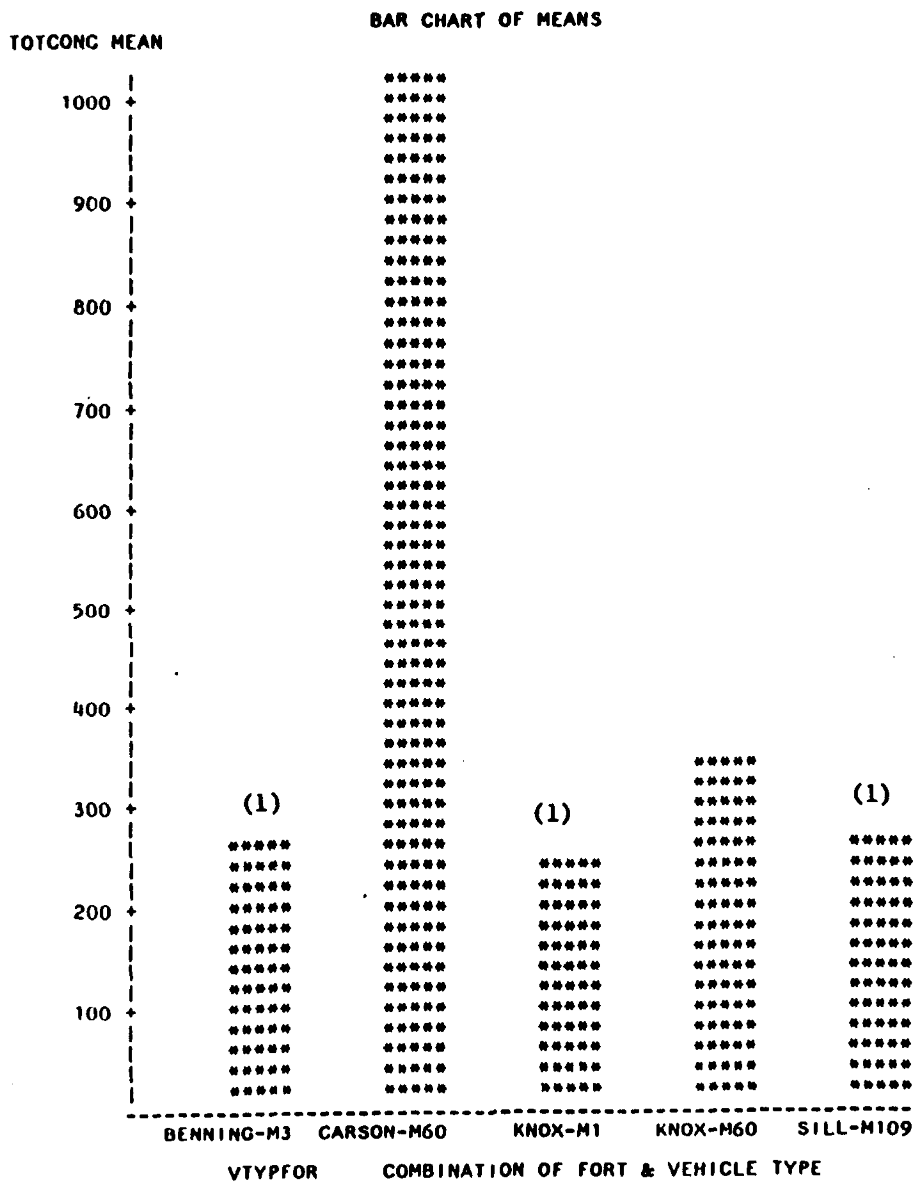
ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	25.0	1180.0	11.0	3700.0	6.0	312.0	12.0	6430.0	13.0	366.0	67.0	6430.0

TABLE 23 (continued)

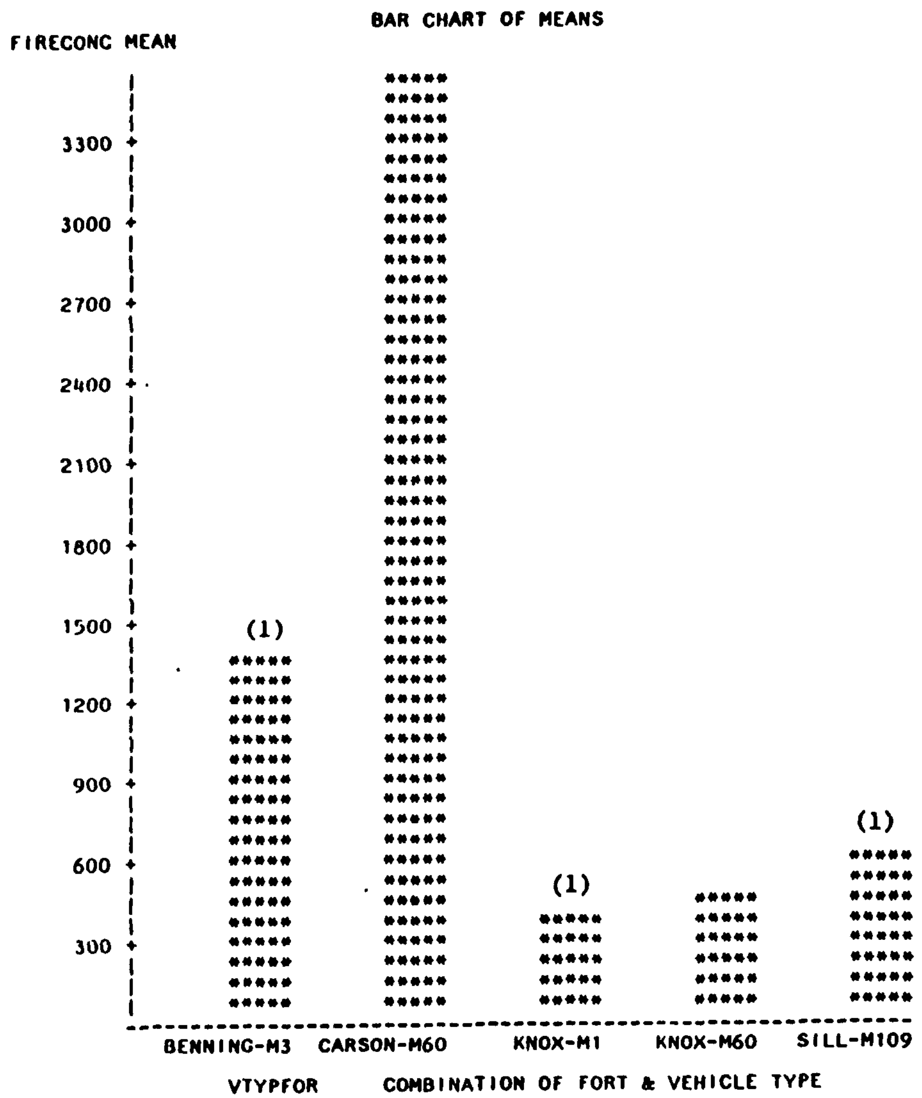
ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY												
COMMAND	1	920.0	.	2755.0	1336.4	247.0	9.9	2465.0	643.5	270.0	135.8	1377.1	1303.7
	2	619.0	68.1	622.5	55.9	.	.	4760.0	2361.7	239.5	152.0	1455.7	2058.4
	3	500.5	477.3	.	.	.	.	.	.	.	.	500.5	477.3
	4	158.5	72.8	.	.	.	.	.	.	.	.	158.5	72.8
	ALL	511.9	314.7	1688.8	1453.4	247.0	9.9	3612.5	1937.3	254.8	119.0	1218.8	1569.6
DRIVER	DAY												
	1	509.5	413.7	1375.5	671.0	215.0	9.9	2445.0	997.0	257.5	133.6	960.5	994.0
	2	540.0	78.4	583.0	131.5	.	.	4265.0	205.1	168.0	86.3	1294.7	1695.0
	3	126.5	12.0	.	.	.	.	.	.	.	.	126.5	12.0
	4	185.4	142.3	.	.	.	.	.	.	.	.	185.4	142.3
	ALL	362.5	253.9	979.3	604.3	215.0	9.9	3355.0	1204.0	212.8	105.4	951.3	1270.2
LOADER	DAY												
	1	726.5	641.3	1920.0	1074.8	280.0	45.3	1945.0	601.0	300.5	92.6	1034.4	917.1
	2	552.5	116.7	851.0	.	.	.	3660.0	2517.3	156.0	14.7	1218.0	1800.1
	3	327.5	205.8	.	.	.	.	.	.	.	.	327.5	205.8
	4	180.8	130.4	.	.	.	.	.	.	.	.	180.8	130.4
	ALL	446.8	345.0	1563.7	979.0	280.0	45.3	2802.5	1792.5	213.8	92.3	959.3	1251.9
ALL	DAY												
	1	678.4	419.1	2016.8	1031.8	247.3	36.0	2285.0	650.6	276.0	96.8	1115.3	1051.9
	2	572.8	80.7	652.4	133.5	.	.	4228.3	1623.0	183.3	81.7	1326.8	1786.8
	3	318.2	286.5	.	.	.	.	.	.	.	.	318.2	286.5
	4	174.9	93.1	.	.	.	.	.	.	.	.	174.9	93.1
	ALL	437.3	298.4	1396.6	1023.3	247.3	36.0	3256.7	1555.5	226.1	97.7	1041.8	1355.0



(1) Most samples below the detection limit.

Figure 22. Concentration (TOTCONC) of nitrogen dioxide (GA) (ug/m^3).



(1) Most samples below the detection limit.

Figure 23. Concentration (FIRECONC) of nitrogen dioxide (GA) (ug/m^3).

TABLE 24. SUMMARY OF NITROGEN DIOXIDE (GA) CONCENTRATION DATA (ug/m^3)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	1.0	166.0	2.0	498.0	2.0	359.0	2.0	602.0	2.0	375.0	9.0	602.0
	2	3.0	547.0	2.0	250.0	.	.	2.0	2590.0	2.0	373.0	9.0	2590.0
	3	2.0	286.0	.	.	.	.	.	.	.	.	2.0	286.0
	4	2.0	178.0	.	.	.	.	.	.	.	.	2.0	178.0
	ALL	8.0	547.0	4.0	498.0	2.0	359.0	4.0	2590.0	4.0	375.0	22.0	2590.0
DRIVER	DAY												
	1	2.0	142.0	2.0	307.0	2.0	357.0	2.0	913.0	2.0	361.0	10.0	913.0
	2	3.0	491.0	2.0	188.0	.	.	2.0	1540.0	2.0	247.0	9.0	1540.0
	3	2.0	78.9	.	.	.	.	.	.	.	.	2.0	78.9
	4	2.0	192.0	.	.	.	.	.	.	.	.	2.0	192.0
	ALL	9.0	491.0	4.0	307.0	2.0	357.0	4.0	1540.0	4.0	361.0	23.0	1540.0
LOADER	DAY												
	1	2.0	173.0	2.0	395.0	2.0	387.0	2.0	1060.0	2.0	375.0	10.0	1060.0
	2	2.0	519.0	1.0	280.0	.	.	2.0	1690.0	3.0	186.0	8.0	1690.0
	3	2.0	264.0	.	.	.	.	.	.	.	.	2.0	264.0
	4	2.0	377.0	.	.	.	.	.	.	.	.	2.0	377.0
	ALL	8.0	519.0	3.0	395.0	2.0	387.0	4.0	1690.0	5.0	375.0	22.0	1690.0
ALL	DAY												
	1	5.0	173.0	6.0	498.0	6.0	387.0	6.0	1060.0	6.0	375.0	29.0	1060.0
	2	8.0	547.0	5.0	280.0	.	.	6.0	2590.0	7.0	373.0	26.0	2590.0
	3	6.0	286.0	.	.	.	.	.	.	.	.	6.0	286.0
	4	6.0	377.0	.	.	.	.	.	.	.	.	6.0	377.0

(CONTINUED)

TABLE 24 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	25.0	547.0	11.0	498.0	6.0	387.0	12.0	2590.0	13.0	375.0	67.0	2590.0

TABLE 24 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY												
COMMAND	1	166.0	.	409.0	125.9	317.0	59.4	372.5	324.6	285.0	127.3	325.9	153.4
	2	508.3	41.8	212.5	53.0	.	.	2180.0	579.8	258.0	162.6	758.4	843.7
	3	198.5	123.7	.	.	.	.	.	.	.	.	198.5	123.7
	4	154.5	33.2	.	.	.	.	.	.	.	.	154.5	33.2
	ALL	299.6	181.7	310.8	138.2	317.0	59.4	1276.3	1111.8	271.5	120.2	475.7	584.8
DRIVER	DAY												
	1	135.0	9.9	243.5	89.8	346.0	15.6	555.5	505.6	271.5	126.6	310.3	230.0
	2	438.0	55.7	160.0	39.6	.	.	1204.0	475.2	181.5	92.6	489.4	458.0
	3	67.1	16.7	.	.	.	.	.	.	.	.	67.1	16.7
	4	166.5	36.1	.	.	.	.	.	.	.	.	166.5	36.1
	ALL	227.9	164.6	201.8	74.4	346.0	15.6	879.8	548.3	226.5	104.4	346.7	342.0
LOADER	DAY												
	1	158.0	21.2	296.5	139.3	379.5	10.6	666.0	557.2	292.5	116.7	358.5	264.8
	2	457.0	87.7	280.0	.	.	.	1196.0	698.6	168.3	15.9	511.4	513.6
	3	190.0	104.7	.	.	.	.	.	.	.	.	190.0	104.7
	4	237.6	197.1	.	.	.	.	.	.	.	.	237.6	197.1
	ALL	260.7	154.5	291.0	99.0	379.5	10.6	931.0	599.8	218.0	90.3	387.8	363.9
ALL	DAY												
	1	150.4	18.6	316.3	119.9	347.5	39.5	531.3	389.7	283.0	96.2	331.8	216.1
	2	469.1	60.0	205.0	59.5	.	.	1526.7	682.7	197.7	87.5	589.3	620.2
	3	151.9	98.2	.	.	.	.	.	.	.	.	151.9	98.2
	4	186.2	99.3	.	.	.	.	.	.	.	.	186.2	99.3
	ALL	261.3	162.9	265.7	109.5	347.5	39.5	1029.0	742.4	237.1	98.2	402.6	439.2

TABLE 24 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	1.0	731.0	2.0	2240.0	2.0	458.0	2.0	2890.0	2.0	561.0	9.0	2890.0
	2	3.0	1020.0	2.0	1160.0	.	.	2.0	8430.0	2.0	532.0	9.0	8430.0
	3	2.0	918.0	.	.	.	.	.	.	.	.	2.0	918.0
	4	2.0	245.0	.	.	.	.	.	.	.	.	2.0	245.0
	ALL	8.0	1020.0	4.0	2240.0	2.0	458.0	4.0	8430.0	4.0	561.0	22.0	8430.0
DRIVER	DAY												
	1	2.0	603.0	2.0	1380.0	2.0	461.0	2.0	4290.0	2.0	540.0	10.0	4290.0
	2	3.0	965.0	2.0	876.0	.	.	2.0	3090.0	2.0	351.0	9.0	3090.0
	3	2.0	255.0	.	.	.	.	.	.	.	.	2.0	255.0
	4	2.0	279.0	.	.	.	.	.	.	.	.	2.0	279.0
	ALL	9.0	965.0	4.0	1380.0	2.0	461.0	4.0	4290.0	4.0	540.0	23.0	4290.0
LOADER	DAY												
	1	2.0	596.0	2.0	1780.0	2.0	494.0	2.0	5170.0	2.0	561.0	10.0	5170.0
	2	2.0	974.0	1.0	1300.0	.	.	2.0	3380.0	3.0	264.0	8.0	3380.0
	3	2.0	865.0	.	.	.	.	.	.	.	.	2.0	865.0
	4	2.0	549.0	.	.	.	.	.	.	.	.	2.0	549.0
	ALL	8.0	974.0	3.0	1780.0	2.0	494.0	4.0	5170.0	5.0	561.0	22.0	5170.0
ALL	DAY												
	1	5.0	731.0	6.0	2240.0	6.0	494.0	6.0	5170.0	6.0	561.0	29.0	5170.0
	2	8.0	1020.0	5.0	1300.0	.	.	6.0	8430.0	7.0	532.0	26.0	8430.0
	3	6.0	918.0	.	.	.	.	.	.	.	.	6.0	918.0
	4	6.0	549.0	.	.	.	.	.	.	.	.	6.0	549.0

(CONTINUED)

TABLE 24 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	25.0	1020.0	11.0	2240.0	6.0	494.0	12.0	8430.0	13.0	561.0	67.0	8430.0

TABLE 24 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY												
COMMAND	1	731.0	.	2170.0	99.0	403.0	77.8	2225.0	940.5	414.0	207.9	1239.4	977.1
	2	948.0	103.8	1027.0	188.1	.	.	5990.0	3450.7	367.0	233.3	1956.9	2607.4
	3	631.5	405.2	.	.	.	.	.	.	.	.	631.5	405.2
	4	217.0	39.6	.	.	.	.	.	.	.	.	217.0	39.6
	ALL	659.0	345.4	1598.5	671.2	403.0	77.8	4107.5	2998.2	390.5	182.5	1384.7	1815.2
DRIVER	DAY												
	1	456.0	207.9	1285.0	134.4	442.5	26.2	3210.0	1527.4	394.5	205.8	1157.6	1250.2
	2	827.7	119.6	775.5	142.1	.	.	2955.0	190.9	257.5	132.2	1162.1	1049.0
	3	217.5	53.0	.	.	.	.	.	.	.	.	217.5	53.0
	4	237.0	59.4	.	.	.	.	.	.	.	.	237.0	59.4
	ALL	478.2	295.3	1030.3	315.1	442.5	26.2	3082.5	900.8	326.0	161.9	997.6	1081.9
LOADER	DAY												
	1	507.0	125.9	1545.0	332.3	480.0	19.8	4045.0	1591.0	424.5	193.0	1400.3	1560.6
	2	847.0	179.6	1300.0	.	.	.	2830.0	777.8	239.0	22.9	1171.4	1132.3
	3	613.5	355.7	.	.	.	.	.	.	.	.	613.5	355.7
	4	342.5	292.0	.	.	.	.	.	.	.	.	342.5	292.0
	ALL	577.5	274.7	1463.3	274.3	480.0	19.8	3437.5	1240.0	313.2	141.1	1149.4	1265.2
ALL	DAY												
	1	531.4	166.9	1666.7	439.5	441.8	51.1	3160.0	1346.7	411.0	157.3	1266.7	1252.6
	2	877.6	123.4	981.0	248.0	.	.	3925.0	2252.0	280.9	125.3	1440.1	1741.8
	3	487.5	320.2	.	.	.	.	.	.	.	.	487.5	320.2
	4	265.5	147.4	.	.	.	.	.	.	.	.	265.5	147.4
	ALL	567.8	302.8	1355.0	499.4	441.8	51.1	3542.5	1813.6	340.9	150.7	1174.5	1404.9

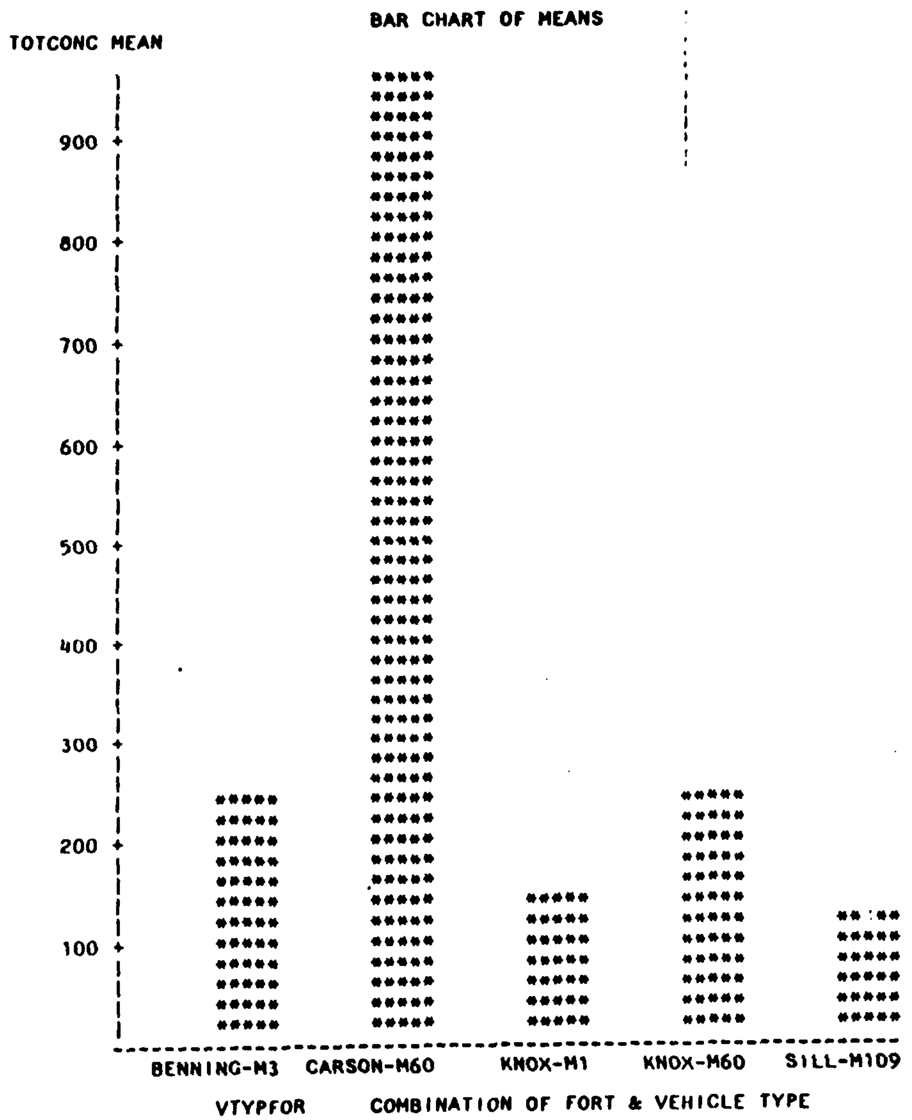


Figure 24. Concentration (TOTCONC) of nitrogen dioxide (BZ) (ug/m^3).

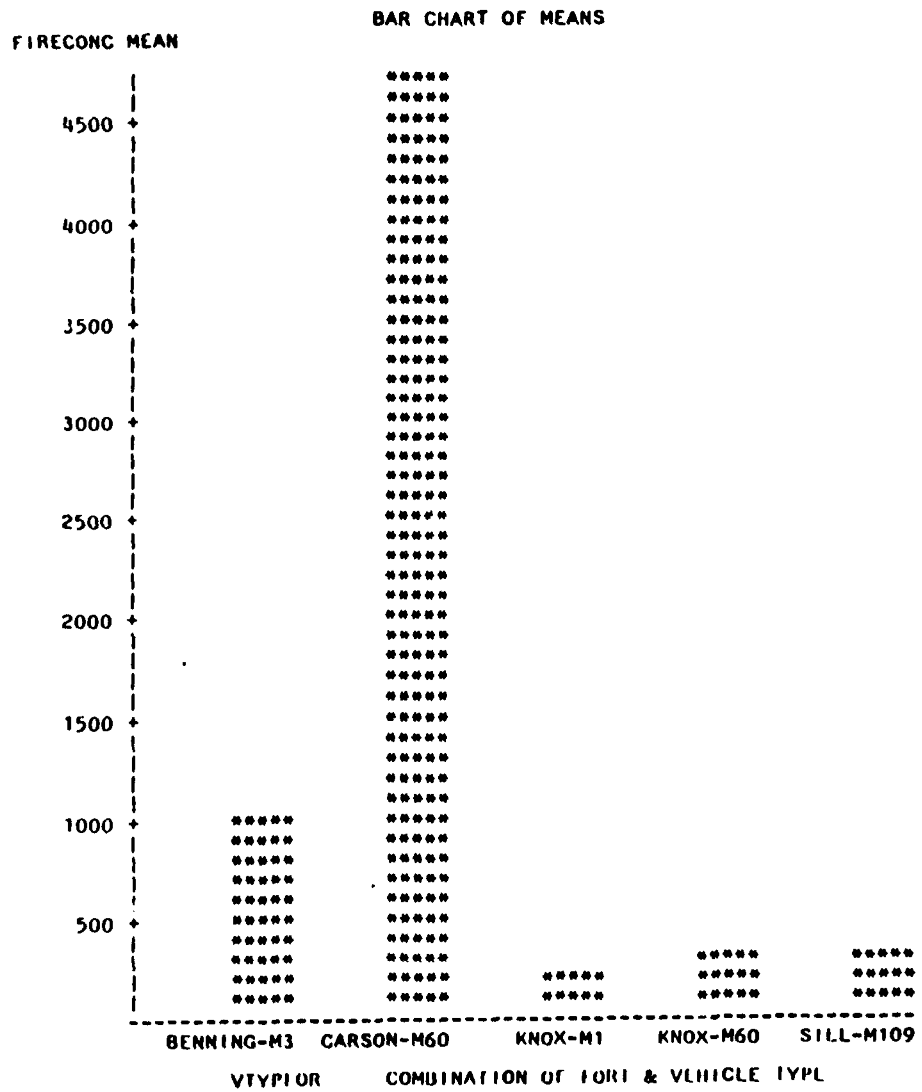


Figure 25. Concentration (FIRECONC) of nitrogen dioxide (BZ) (ug/m^3).

TABLE 25. SUMMARY OF NITROGEN DIOXIDE (BZ) CONCENTRATION DATA (ppb)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	2.0	106.0	1.0	194.0	2.0	227.0	2.0	1240.0	2.0	117.0	9.0	1240.0
	2	3.0	228.0	3.0	543.0	.	.	2.0	1390.0	2.0	213.0	10.0	1390.0
	3	2.0	152.0	.	.	.	.	.	.	.	.	2.0	152.0
	4	2.0	45.8	.	.	.	.	.	.	.	.	2.0	45.8
	ALL	9.0	228.0	4.0	543.0	2.0	227.0	4.0	1390.0	4.0	213.0	23.0	1390.0
DRIVER	DAY												
	1	2.0	136.0	2.0	225.0	2.0	294.0	2.0	515.0	2.0	117.0	10.0	515.0
	2	3.0	345.0	3.0	357.0	.	.	2.0	2550.0	2.0	205.0	10.0	2550.0
	3	2.0	40.9	.	.	.	.	.	.	.	.	2.0	40.9
	4	2.0	69.8	.	.	.	.	.	.	.	.	2.0	69.8
	ALL	9.0	345.0	5.0	357.0	2.0	294.0	4.0	2550.0	4.0	205.0	24.0	2550.0
GUNNER	DAY												
	1	.	.	.	.	2.0	633.0	2.0	411.0	2.0	311.0	6.0	633.0
	2	.	.	.	.	.	.	2.0	1200 0	2.0	166.0	4.0	1200.0
	ALL	.	.	.	.	2.0	633.0	4.0	1200.0	4.0	311.0	10.0	1200.0
LOADER	DAY												
	1	2.0	110.0	2.0	297.0	2.0	154.0	2.0	1360.0	2.0	112.0	10.0	1360.0
	2	3.0	218.0	3.0	331.0	.	.	2.0	1490.0	2.0	281.0	10.0	1490.0
	3	2.0	29.3	.	.	.	.	.	.	.	.	2.0	29.3
	4	2.0	99.9	.	.	.	.	.	.	.	.	2.0	99.9
	ALL	9.0	218.0	5.0	331.0	2.0	154.0	4.0	1490.0	4.0	281.0	24.0	1490.0

(CONTINUED)

TABLE 25 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY												
	1	6.0	136.0	5.0	297.0	8.0	633.0	8.0	1360.0	8.0	311.0	35.0	1360.0
	2	9.0	345.0	9.0	543.0	.	.	8.0	2550.0	8.0	281.0	34.0	2550.0
	3	6.0	152.0	.	.	.	.	.	.	.	.	6.0	152.0
	4	6.0	99.9	.	.	.	.	.	.	.	.	6.0	99.9
	ALL	27.0	345.0	14.0	543.0	8.0	633.0	16.0	2550.0	16.0	311.0	81.0	2550.0

TABLE 25 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY												
COMMAND	1	100.3	8.1	194.0	.	224.0	4.2	806.0	613.8	88.4	40.4	292.4	367.8
	2	181.0	55.3	367.3	228.5	.	.	1113.5	391.0	135.9	109.0	414.4	418.7
	3	86.1	93.2	.	.	.	.	.	.	.	.	86.1	93.2
	4	45.8	0.0	.	.	.	.	.	.	.	.	45.8	0.0
	ALL	111.9	70.3	324.0	205.7	224.0	4.2	959.8	456.1	112.1	72.5	306.0	370.5
DRIVER	DAY												
	1	119.5	23.3	200.5	34.6	177.5	164.7	375.0	198.0	98.1	26.7	194.1	135.2
	2	290.0	53.6	224.0	117.2	.	.	1770.5	1102.4	115.3	126.8	531.4	755.7
	3	33.5	10.4	.	.	.	.	.	.	.	.	33.5	10.4
	4	69.8	0.0	.	.	.	.	.	.	.	.	69.8	0.0
	ALL	146.2	115.6	214.6	85.6	177.5	164.7	1072.8	1033.1	106.7	75.5	310.9	519.1
GUNNER	DAY												
	1	.	.	.	.	422.5	297.7	323.0	124.5	182.2	182.2	309.2	197.8
	2	.	.	.	.	.	.	941.5	365.6	163.5	3.5	552.5	496.3
	ALL	.	.	.	.	422.5	297.7	632.3	421.0	172.8	105.7	406.5	345.9
LOADER	DAY												
	1	97.0	18.3	250.0	66.5	130.0	33.9	924.5	615.9	80.9	43.9	296.5	395.6
	2	187.7	32.1	199.3	118.6	.	.	1385.0	148.5	239.5	58.7	441.0	504.1
	3	29.1	0.3	.	.	.	.	.	.	.	.	29.1	0.3
	4	69.9	42.4	.	.	.	.	.	.	.	.	69.9	42.4
	ALL	106.1	69.6	219.6	94.4	130.0	33.9	1154.8	452.2	160.2	100.8	315.5	424.4
ALL	DAY												
	1	105.6	17.5	219.0	47.0	238.5	175.7	607.1	440.9	112.4	85.1	268.4	293.5

(CONTINUED)

TABLE 25 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ALL	DAY												
	2	219.6	67.4	263.6	161.8	.	.	1302.6	574.2	163.6	83.8	472.9	546.3
	3	49.6	50.6	.	.	.	.	.	.	.	.	49.6	50.6
	4	61.8	22.7	.	.	.	.	.	.	.	.	61.8	22.7
	ALL	121.4	86.3	247.6	131.4	238.5	175.7	954.9	611.2	138.0	85.8	322.7	426.0

TABLE 25 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	2.0	467.0	1.0	1280.0	2.0	289.0	2.0	16300	2.0	160.0	9.0	16300
	2	3.0	449.0	3.0	2530.0	.	.	2.0	2780.0	2.0	303.0	10.0	2780.0
	3	2.0	487.0	.	.	.	.	.	.	.	.	2.0	487.0
	4	2.0	65.5	.	.	.	.	.	.	.	.	2.0	65.5
	ALL	9.0	487.0	4.0	2530.0	2.0	289.0	4.0	16300	4.0	303.0	23.0	16300
DRIVER	DAY												
	1	2.0	452.0	2.0	1160.0	2.0	375.0	2.0	3090.0	2.0	160.0	10.0	3090.0
	2	3.0	617.0	3.0	912.0	.	.	2.0	5090.0	2.0	291.0	10.0	5090.0
	3	2.0	131.0	.	.	.	.	.	.	.	.	2.0	131.0
	4	2.0	99.7	.	.	.	.	.	.	.	.	2.0	99.7
	ALL	9.0	617.0	5.0	1160.0	2.0	375.0	4.0	5090.0	4.0	291.0	24.0	5090.0
GUNNER	DAY												
	1	.	.	.	.	2.0	802.0	2.0	3090.0	2.0	428.0	6.0	3090.0
	2	.	.	.	.	.	.	2.0	2410.0	2.0	236.0	4.0	2410.0
	ALL	.	.	.	.	2.0	802.0	4.0	3090.0	4.0	428.0	10.0	3090.0
LOADER	DAY												
	1	2.0	482.0	2.0	1340.0	2.0	196.0	2.0	17900	2.0	167.0	10.0	17900
	2	3.0	430.0	3.0	773.0	.	.	2.0	4160.0	2.0	401.0	10.0	4160.0
	3	2.0	92.8	.	.	.	.	.	.	.	.	2.0	92.8
	4	2.0	143.0	.	.	.	.	.	.	.	.	2.0	143.0
	ALL	9.0	482.0	5.0	1340.0	2.0	196.0	4.0	17900	4.0	401.0	24.0	17900

(CONTINUED)

TABLE 25 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY												
	1	6.0	482.0	5.0	1340.0	8.0	802.0	8.0	17900	8.0	428.0	35.0	17900
	2	9.0	617.0	9.0	2530.0	.	.	8.0	5090.0	8.0	401.0	34.0	5090.0
	3	6.0	487.0	.	.	.	.	.	.	.	.	6.0	487.0
	4	6.0	143.0	.	.	.	.	.	.	.	.	6.0	143.0
	ALL	27.0	617.0	14.0	2530.0	8.0	802.0	16.0	17900	16.0	428.0	81.0	17900

TABLE 25 (continued)

ALL

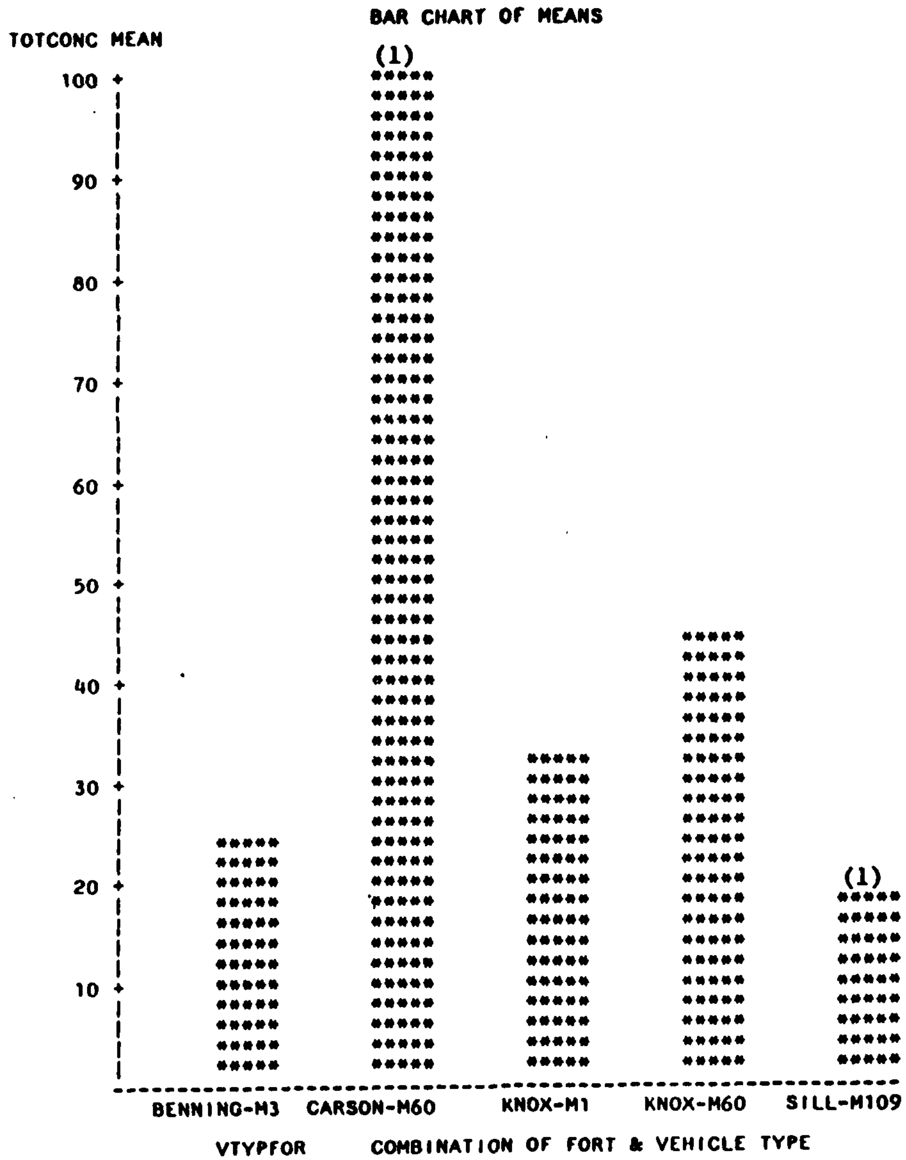
POSITION	DAY	SILL-M109 FIRECONC MEAN	SILL-M109 FIRECONC STD	BENNING-M3 FIRECONC MEAN	BENNING-M3 FIRECONC STD	KNOX-M60 FIRECONC MEAN	KNOX-M60 FIRECONC STD	CARSON-M60 FIRECONC MEAN	CARSON-M60 FIRECONC STD	KNOX-M1 FIRECONC MEAN	KNOX-M1 FIRECONC STD	ALL FIRECONC MEAN	ALL FIRECONC STD
COMMAND	1	347.5	169.0	1280.0	.	285.0	5.7	9040.0	10267	124.7	49.9	2319.4	5274.3
	2	343.0	119.2	1253.3	1107.2	.	.	2750.0	42.4	193.1	155.4	1067.5	1124.2
	3	275.2	299.5	.	.	.	.	.	.	.	.	275.2	299.5
	4	64.4	1.6	.	.	.	.	.	.	.	.	64.4	1.6
	ALL	267.0	180.0	1260.0	904.1	285.0	5.7	5895.0	6951.8	158.9	102.2	1401.3	3363.1
DRIVER	1	390.5	87.0	1085.0	106.1	226.3	210.4	2780.0	438.4	139.5	29.0	924.3	1052.6
	2	541.3	74.1	694.3	194.9	.	.	4155.0	1322.3	163.6	180.1	1234.4	1617.2
	3	106.7	34.4	.	.	.	.	.	.	.	.	106.7	34.4
	4	98.1	2.3	.	.	.	.	.	.	.	.	98.1	2.3
	ALL	312.7	213.8	850.6	260.0	226.3	210.4	3467.5	1130.1	151.6	106.2	916.5	1271.3
GUNNER	1	.	.	.	.	536.5	375.5	2530.0	792.0	253.9	246.2	1106.8	1182.0
	2	.	.	.	.	.	.	2315.0	134.4	232.0	5.7	1273.5	1205.1
	ALL	.	.	.	.	536.5	375.5	2422.5	480.1	242.9	142.8	1173.5	1125.9
LOADER	1	342.5	197.3	1340.0	0.0	165.5	43.1	10125	10996	117.8	69.7	2418.1	5491.5
	2	353.3	71.3	595.3	154.2	.	.	3565.0	841.5	341.0	84.9	1065.8	1354.1
	3	92.4	0.5	.	.	.	.	.	.	.	.	92.4	0.5
	4	99.0	62.2	.	.	.	.	.	.	.	.	99.0	62.2
	ALL	236.4	156.4	893.2	422.2	165.5	43.1	6845.0	7408.2	229.4	143.6	1467.6	3648.1
ALL	1	360.2	124.8	1226.0	141.4	303.3	222.5	6118.8	6807.1	159.0	115.5	1741.1	3939.2

(CONTINUED)

TABLE 25 (continued)

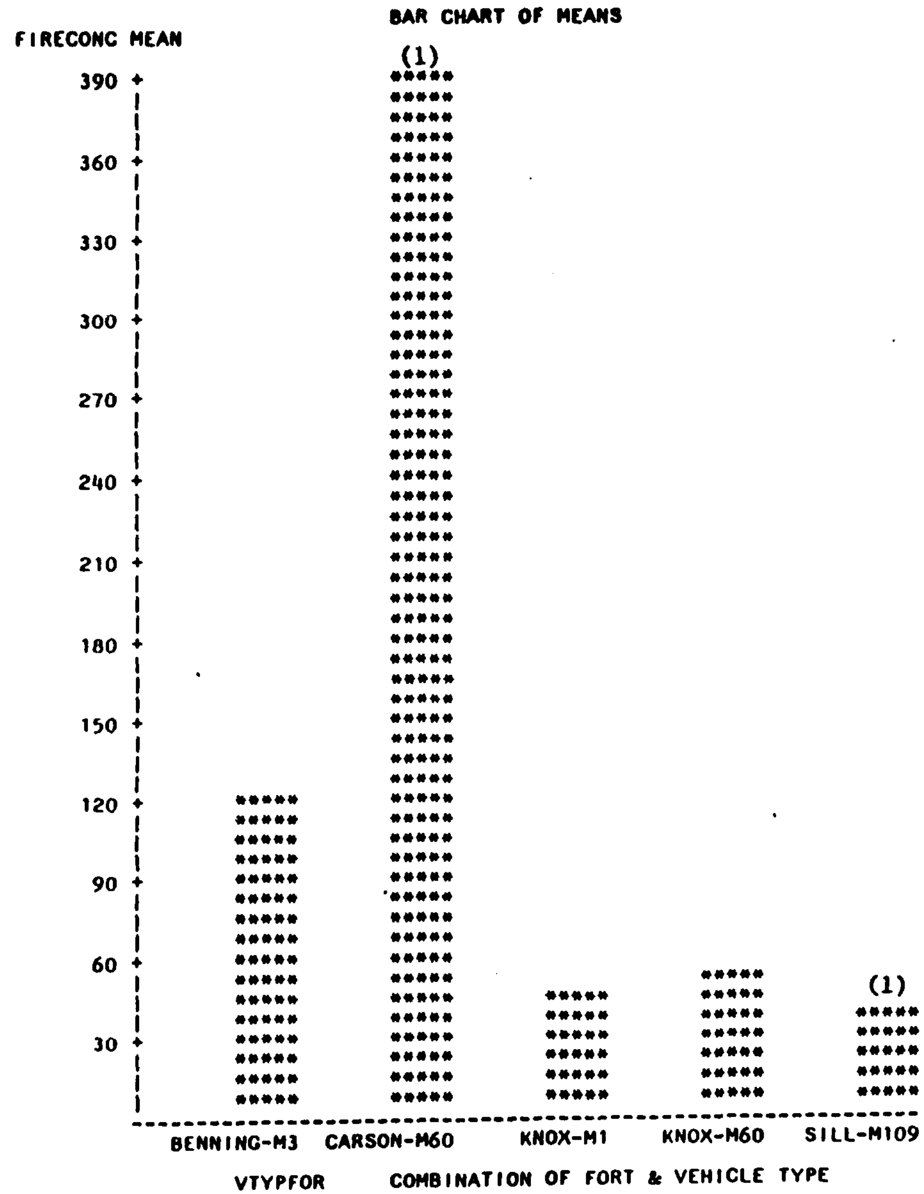
ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ALL	DAY												
	2	412.6	124.7	847.7	645.2	.	.	3196.3	966.5	232.4	119.5	1140.3	1303.1
	3	158.1	162.6	.	.	.	.	.	.	.	.	158.1	162.6
	4	87.2	33.0	.	.	.	.	.	.	.	.	87.2	33.0
	ALL	272.1	180.5	982.8	545.6	303.3	222.5	4657.5	4933.3	195.7	119.7	1249.2	2756.6



(1) Most samples below the detection limit.

Figure 26. Concentration (TOTCONC) of formaldehyde (ug/m^3).



(1) Most samples below the detection limit.

Figure 27. Concentration (FIRECONC) of formaldehyde (ug/m^3).

TABLE 26. SUMMARY OF FORMALDEHYDE CONCENTRATION DATA (ug/m^3)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	4.0	10.5	4.0	38.9	4.0	48.7	4.0	112.0	4.0	49.6	20.0	112.0
	2	4.0	33.6	4.0	18.1	.	.	4.0	229.0	4.0	52.5	16.0	229.0
	3	4.0	18.8	.	.	.	.	.	.	.	.	4.0	18.8
	4	4.0	16.8	.	.	.	.	.	.	.	.	4.0	16.8
	ALL	16.0	33.6	8.0	38.9	4.0	48.7	8.0	229.0	8.0	52.5	44.0	229.0
DRIVER	DAY												
	1	4.0	11.5	4.0	27.3	4.0	79.5	4.0	106.0	4.0	46.2	20.0	106.0
	2	4.0	39.1	4.0	29.6	.	.	5.0	205.0	4.0	56.6	17.0	205.0
	3	4.0	16.1	.	.	.	.	.	.	.	.	4.0	16.1
	4	4.0	19.7	.	.	.	.	.	.	.	.	4.0	19.7
	ALL	16.0	39.1	8.0	29.6	4.0	79.5	9.0	205.0	8.0	56.6	45.0	205.0
GUNNER	DAY												
	1	.	.	.	.	2.0	51.2	1.0	32.2	2.0	27.6	5.0	51.2
	2	.	.	.	.	.	.	1.0	196.0	2.0	34.8	3.0	196.0
	ALL	.	.	.	.	2.0	51.2	2.0	196.0	4.0	34.8	8.0	196.0
LOADER	DAY												
	1	4.0	10.9	4.0	46.5	4.0	56.6	4.0	118.0	4.0	59.1	20.0	118.0
	2	4.0	32.6	4.0	30.3	.	.	4.0	199.0	5.0	38.0	17.0	199.0
	3	4.0	18.2	.	.	.	.	.	.	.	.	4.0	18.2
	4	4.0	27.8	.	.	.	.	.	.	.	.	4.0	27.8
	ALL	16.0	32.6	8.0	46.5	4.0	56.6	8.0	199.0	9.0	59.1	45.0	199.0

(CONTINUED)

TABLE 26 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY												
	1	12.0	11.5	12.0	46.5	14.0	79.5	13.0	118.0	14.0	59.1	65.0	118.0
	2	12.0	39.1	12.0	30.3	.	.	14.0	229.0	15.0	56.6	53.0	229.0
	3	12.0	18.8	.	.	.	.	.	.	.	.	12.0	18.8
	4	12.0	27.8	.	.	.	.	.	.	.	.	12.0	27.8
	ALL	48.0	39.1	24.0	46.5	14.0	79.5	27.0	229.0	29.0	59.1	142.0	229.0

TABLE 26 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY												
COMMAND	1	9.9	0.5	27.5	8.1	38.0	10.9	69.9	41.3	31.9	12.1	35.4	26.9
	2	31.7	1.3	16.1	2.0	.	.	144.9	93.8	40.7	8.4	58.4	67.3
	3	10.6	5.5	.	.	.	.	.	.	.	.	10.6	5.5
	4	13.3	4.8	.	.	.	.	.	.	.	.	13.3	4.8
	ALL	16.4	9.8	21.8	8.2	38.0	10.9	107.4	78.2	36.3	10.8	39.5	46.7
DRIVER	DAY												
	1	10.7	0.9	20.8	4.4	50.1	23.5	66.0	38.7	34.3	10.8	36.4	27.6
	2	34.8	3.3	22.9	7.1	.	.	122.6	78.2	35.5	15.1	58.0	58.8
	3	11.2	4.0	.	.	.	.	.	.	.	.	11.2	4.0
	4	17.6	2.0	.	.	.	.	.	.	.	.	17.6	2.0
	ALL	18.6	10.4	21.8	5.6	50.1	23.5	97.4	67.1	34.9	12.2	40.6	42.9
GUNNER	DAY												
	1	.	.	.	.	41.6	13.6	32.2	.	25.7	2.6	33.4	10.5
	2	.	.	.	.	.	.	196.0	.	29.1	8.0	84.8	96.5
	ALL	.	.	.	.	41.6	13.6	114.1	115.8	27.4	5.2	52.6	58.6
LOADER	DAY												
	1	9.6	1.2	29.0	12.3	44.4	11.3	69.0	42.8	31.9	18.5	36.8	28.1
	2	31.1	1.9	23.8	5.9	.	.	113.9	68.8	24.2	9.8	46.9	48.9
	3	11.4	4.7	.	.	.	.	.	.	.	.	11.4	4.7
	4	18.7	6.2	.	.	.	.	.	.	.	.	18.7	6.2
	ALL	17.7	9.5	26.4	9.4	44.4	11.3	91.4	58.2	27.6	13.9	36.7	36.7
ALL	DAY												
	1	10.1	0.9	25.8	8.9	43.8	14.9	65.5	36.9	31.7	12.1	36.0	26.2

(CONTINUED)

TABLE 26 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ALL	DAY												
	2	32.6	2.7	20.9	6.1	.	.	131.7	74.2	32.3	12.0	56.0	59.5
	3	11.1	4.3	.	.	.	.	.	.	.	.	11.1	4.3
	4	16.5	4.9	.	.	.	.	.	.	.	.	16.5	4.9
	ALL	17.6	9.7	23.4	7.8	43.8	14.9	99.9	67.2	32.0	11.9	39.7	42.9

TABLE 26 (continued)

ALL

POSITION	DAY	SILL-M109 FIRECONC # OF VEHS.	SILL-M109 FIRECONC MAX	BENNING-M3 FIRECONC # OF VEHS.	BENNING-M3 FIRECONC MAX	KNOX-M60 FIRECONC # OF VEHS.	KNOX-M60 FIRECONC MAX	CARSON-M60 FIRECONC # OF VEHS.	CARSON-M60 FIRECONC MAX	KNOX-M1 FIRECONC # OF VEHS.	KNOX-M1 FIRECONC MAX	ALL FIRECONC # OF VEHS.	ALL FIRECONC MAX
		COMBINATION OF FORT & VEHICLE TYPE											
COMMAND	1	4.0	44.4	4.0	258.0	4.0	60.4	4.0	494.0	4.0	68.1	20.0	494.0
	2	4.0	64.5	4.0	92.2	.	.	4.0	458.0	4.0	74.7	16.0	458.0
	3	4.0	38.6	.	.	.	.	.	.	.	.	4.0	38.6
	4	4.0	23.3	.	.	.	.	.	.	.	.	4.0	23.3
	ALL	16.0	64.5	8.0	258.0	4.0	60.4	8.0	494.0	8.0	74.7	44.0	494.0
DRIVER	1	4.0	45.1	4.0	181.0	4.0	103.0	4.0	483.0	4.0	69.0	20.0	483.0
	2	4.0	76.8	4.0	151.0	.	.	5.0	410.0	4.0	80.7	17.0	410.0
	3	4.0	35.0	.	.	.	.	.	.	.	.	4.0	35.0
	4	4.0	28.5	.	.	.	.	.	.	.	.	4.0	28.5
	ALL	16.0	76.8	8.0	181.0	4.0	103.0	9.0	483.0	8.0	80.7	45.0	483.0
GUNNER	1	.	.	.	.	2.0	63.5	1.0	335.0	2.0	41.3	5.0	335.0
	2	.	.	.	.	.	.	1.0	391.0	2.0	49.6	3.0	391.0
	ALL	.	.	.	.	2.0	63.5	2.0	391.0	4.0	49.6	8.0	391.0
LOADER	1	4.0	45.7	4.0	308.0	4.0	72.2	4.0	499.0	4.0	88.4	20.0	499.0
	2	4.0	65.8	4.0	155.0	.	.	4.0	399.0	5.0	54.2	17.0	399.0
	3	4.0	39.8	.	.	.	.	.	.	.	.	4.0	39.8
	4	4.0	40.5	.	.	.	.	.	.	.	.	4.0	40.5
	ALL	16.0	65.8	8.0	308.0	4.0	72.2	8.0	499.0	9.0	88.4	45.0	499.0

(CONTINUED)

TABLE 26 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY												
	1	12.0	45.7	12.0	308.0	14.0	103.0	13.0	499.0	14.0	88.4	65.0	499.0
	2	12.0	76.8	12.0	155.0	.	.	14.0	458.0	15.0	80.7	53.0	458.0
	3	12.0	39.8	.	.	.	.	.	.	.	.	12.0	39.8
	4	12.0	40.5	.	.	.	.	.	.	.	.	12.0	40.5
	ALL	48.0	76.8	24.0	308.0	14.0	103.0	27.0	499.0	29.0	88.4	142.0	499.0

TABLE 26 (continued)

ALL

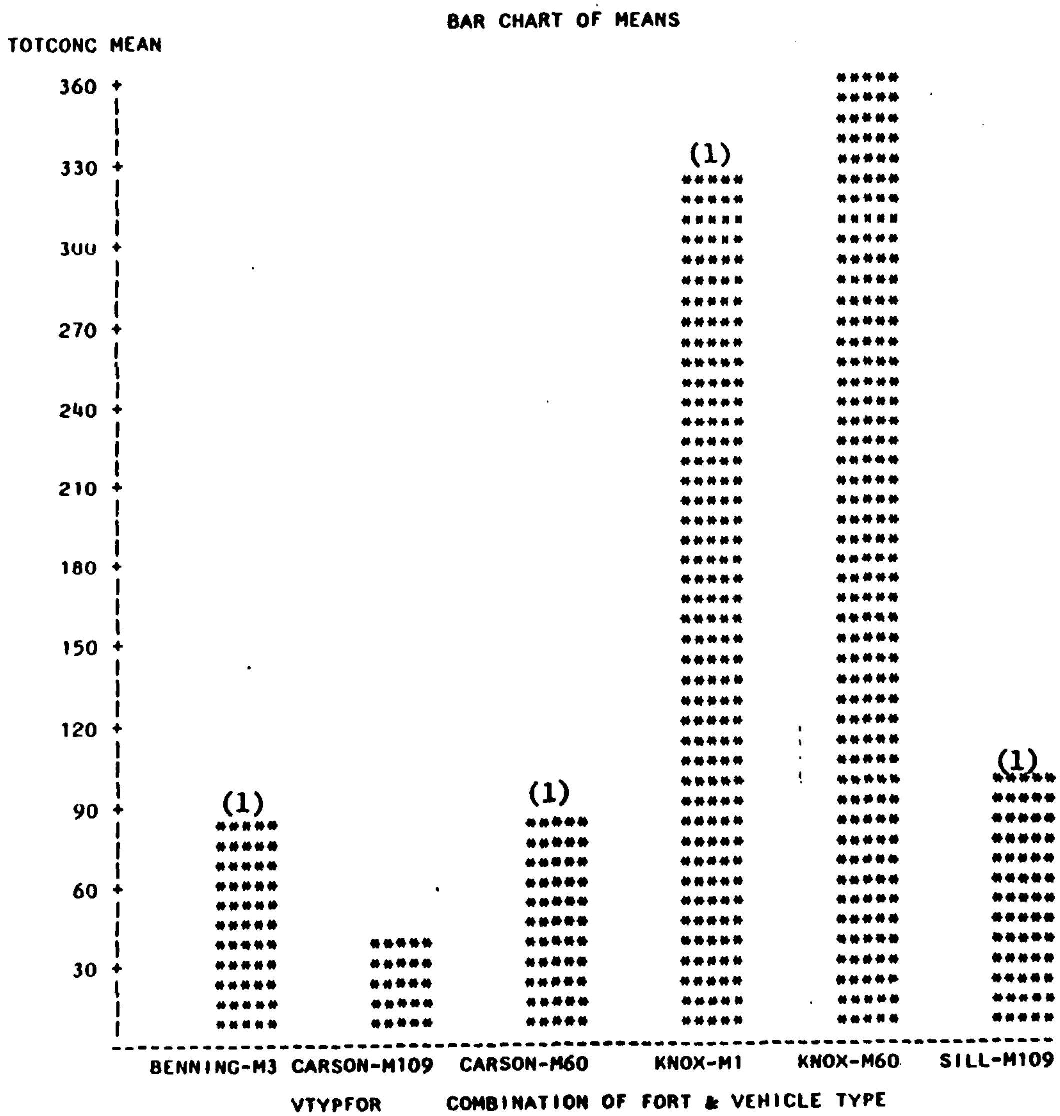
		SILL-M109 FIRECONC MEAN	SILL-M109 FIRECONC STD	BENNING-M3 FIRECONC MEAN	BENNING-M3 FIRECONC STD	KNOX-M60 FIRECONC MEAN	KNOX-M60 FIRECONC STD	CARSON-M60 FIRECONC MEAN	CARSON-M60 FIRECONC STD	KNOX-M1 FIRECONC MEAN	KNOX-M1 FIRECONC STD	ALL FIRECONC MEAN	ALL FIRECONC STD
POSITION	DAY												
COMMAND	1	32.9	11.5	159.1	76.9	47.5	14.0	425.8	68.0	44.7	17.0	142.0	158.6
	2	59.1	4.2	78.5	10.8	.	.	392.5	62.7	57.8	12.0	147.0	149.5
	3	26.3	9.4	.	.	.	.	.	.	.	.	26.3	9.4
	4	18.6	6.6	.	.	.	.	.	.	.	.	18.6	6.6
	ALL	34.2	17.4	118.8	66.6	47.5	14.0	409.1	63.1	51.3	15.3	122.1	145.5
DRIVER	DAY												
	1	34.7	10.1	110.5	47.3	63.3	30.8	405.5	66.0	48.5	17.6	132.5	146.8
	2	65.3	10.8	112.7	38.6	.	.	341.0	59.9	50.4	21.7	154.0	131.5
	3	28.3	4.5	.		.	.	.	.	.	.	28.3	4.5
	4	24.9	3.4	.	.	.	.	.	.	.	.	24.9	3.4
	ALL	38.3	18.0	111.6	40.0	63.3	30.8	369.7	67.7	49.5	18.3	121.8	133.0
GUNNER	DAY												
	1	.	.	.	.	51.4	17.0	335.0	.	35.3	8.4	101.7	131.0
	2	.	.	.	.	.	.	391.0	.	41.4	11.6	157.9	202.0
	ALL	.	.	.	.	51.4	17.0	363.0	39.6	38.4	9.0	122.8	149.4
LOADER	DAY												
	1	31.0	10.6	158.8	102.6	55.6	14.7	412.5	74.5	45.7	29.3	140.7	155.9
	2	58.5	6.9	117.6	34.9	.	.	382.3	18.4	34.4	13.9	141.5	142.4
	3	28.6	7.8	.	.	.	.	.	.	.	.	28.6	7.8
	4	26.5	9.6	.	.	.	.	.	.	.	.	26.5	9.6
	ALL	36.2	15.6	138.2	74.3	55.6	14.7	397.4	52.8	39.4	21.3	120.9	140.7
ALL	DAY												
	1	32.9	9.9	142.8	75.2	54.9	19.4	408.5	64.7	44.7	19.0	135.6	149.2

(CONTINUED)

TABLE 26 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ALL	DAY												
	2	60.9	7.8	102.9	33.2	..	.	371.1	51.4	45.8	17.1	148.1	140.0
	3	27.7	6.9	.	.	.	.	.	.	.	.	27.7	6.9
	4	23.3	7.3	.	.	.	.	.	.	.	.	23.3	7.3
	ALL	36.2	16.7	122.9	60.4	54.9	19.4	389.1	60.1	45.3	17.7	121.7	138.8



(1) Most samples below the detection limit.

Figure 28. Concentration (TOTCONC) of ammonia (ug/m^3).

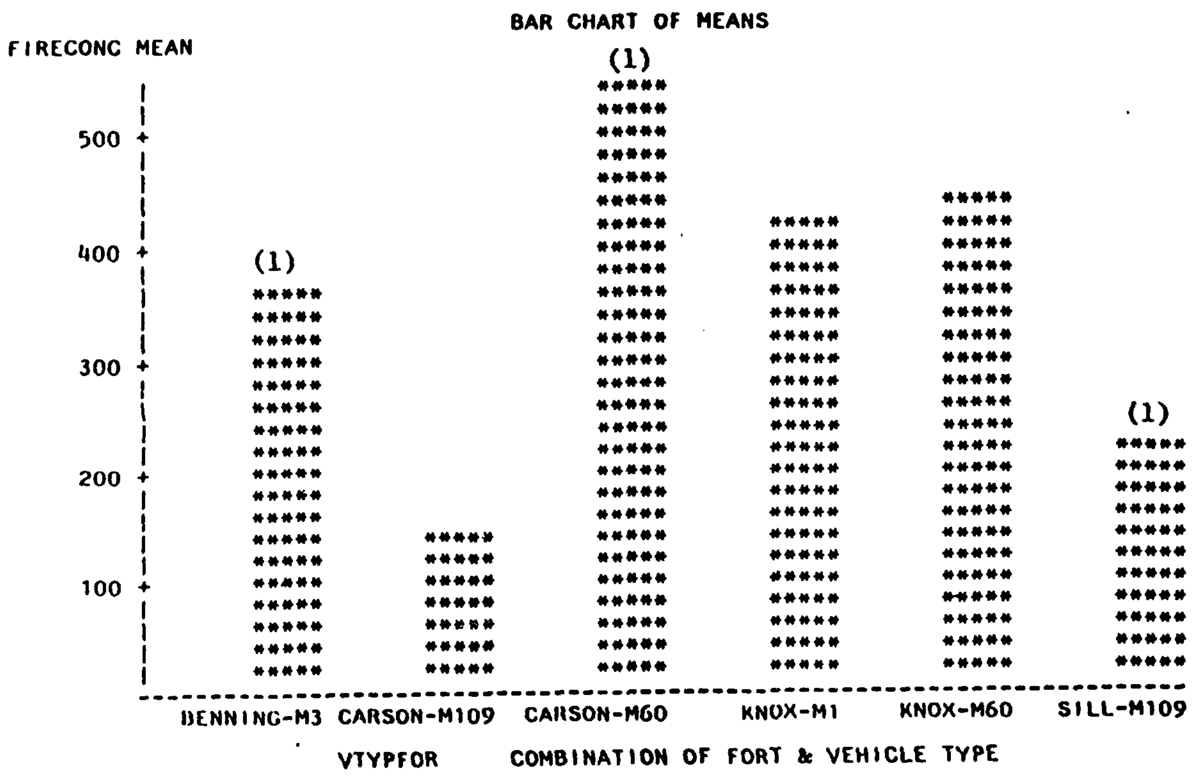


Figure 29. Concentration (FIRECONC) of ammonia (ug/m^3).

TABLE 27. SUMMARY OF AMMONIA CONCENTRATION DATA (ug/m^3)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY														
COMMAND	1	3.0	72.5	2.0	87.8	3.0	169.0	2.0	650.0	2.0	299.0	3.0	564.0	15.0	650.0
	2	2.0	264.0	.	.	2.0	102.0	.	.	2.0	60.5	2.0	697.0	8.0	697.0
	3	2.0	62.9	.	.	.	.	.	.	.	.	.	.	2.0	62.9
	4	2.0	92.0	.	.	.	.	.	.	.	.	.	.	2.0	92.0
	ALL	9.0	264.0	2.0	87.8	5.0	169.0	2.0	650.0	4.0	299.0	5.0	697.0	27.0	697.0
DRIVER	DAY														
	1	3.0	232.0	2.0	24.0	3.0	75.5	2.0	110.0	2.0	86.6	2.0	235.0	14.0	235.0
	2	2.0	298.0	.	.	2.0	86.5	.	.	2.0	34.5	2.0	129.0	8.0	298.0
	3	2.0	32.1	.	.	.	.	.	.	.	.	.	.	2.0	32.1
	4	2.0	227.0	.	.	.	.	.	.	.	.	.	.	2.0	227.0
	ALL	9.0	298.0	2.0	24.0	5.0	86.5	2.0	110.0	4.0	86.6	4.0	235.0	26.0	298.0
LOADER	DAY														
	1	3.0	142.0	2.0	40.8	3.0	76.5	2.0	836.0	2.0	180.0	3.0	483.0	15.0	836.0
	2	2.0	176.0	.	.	2.0	68.9	.	.	2.0	28.9	2.0	512.0	8.0	512.0
	3	2.0	32.1	.	.	.	.	.	.	.	.	.	.	2.0	32.1
	4	3.0	79.3	.	.	.	.	.	.	.	.	.	.	3.0	79.3
	ALL	10.0	176.0	2.0	40.8	5.0	76.5	2.0	836.0	4.0	180.0	5.0	512.0	28.0	836.0
ALL	DAY														
	1	9.0	232.0	6.0	87.8	9.0	169.0	6.0	836.0	6.0	299.0	8.0	564.0	44.0	836.0
	2	6.0	298.0	.	.	6.0	102.0	.	.	6.0	60.5	6.0	697.0	24.0	697.0
	3	6.0	62.9	.	.	.	.	.	.	.	.	.	.	6.0	62.9
	4	7.0	227.0	.	.	.	.	.	.	.	.	.	.	7.0	227.0

(CONTINUED)

TABLE 27 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	28.0	298.0	6.0	87.8	15.0	169.0	6.0	836.0	12.0	299.0	14.0	697.0	81.0	836.0

TABLE 27 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TO CONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY														
COMMAND	1	55.6	14.6	55.	45.4	110.0	51.9	400.0	353.6	200.5	139.3	372.0	202.7	195.0	194.8
	2	219.0	63.6	.	.	87.4	20.6	.	.	48.5	17.0	520.5	249.6	218.8	220.9
	3	47.3	22.0	.	.	.	.	.	.	.	.	.	.	47.3	22.0
	4	74.8	24.4		.	.	.	.	.	.	.	.	.	74.8	24.4
	ALL	94.3	76.1	55.7	45.4	100.9	40.1	400.0	353.6	124.5	119.4	431.4	206.7	182.2	190.8
DRIVER	DAY														
	1	114.0	103.1	23.7	0.4	73.2	2.4	100.5	13.4	73.7	18.2	143.0	130.0	88.8	65.9
	2	207.0	128.7		.	84.8	2.3	.	.	29.8	6.6	127.5	2.1	112.3	84.6
	3	29.3	4.0	.	.	.	.	.	.	.	.	.	.	29.3	4.0
	4	153.3	104.2	.	.	.	.	.	.	.	.	.	.	153.3	104.2
	ALL	124.6	101.5	23.7	0.4	77.9	6.7	100.5	13.4	51.8	27.7	135.3	75.6	96.4	73.7
LOADER	DAY														
	1	87.8	51.9	32.7	11.4	67.0	8.5	575.5	368.4	122.5	81.3	340.0	140.6	196.4	221.5
	2	133.7	59.8	.	.	68.4	0.6	.	.	27.6	1.8	420.5	129.4	162.6	172.9
	3	31.4	0.9	.	.	.	.	.	.	.	.	.	.	31.4	0.9
	4	53.1	24.0	.	.	.	.	.	.	.	.	.	.	53.1	24.0
	ALL	75.3	50.3	32.7	11.4	67.6	6.1	575.5	368.4	75.0	72.2	372.2	126.5	159.6	191.0
ALL	DAY														
	1	85.8	63.5	37.4	25.6	83.4	33.1	358.7	313.6	132.2	92.4	302.8	172.5	161.7	179.4
	2	186.6	80.9	.	.	80.2	13.1	.	.	35.3	13.1	356.2	221.8	164.6	167.6
	3	36.0	13.3	.	.	.	.	.	.	.	.	.	.	36.0	13.3
	4	87.9	64.7	.	.	.	.	.	.	.	.	.	.	87.9	64.7
	ALL	97.3	77.7	37.4	25.6	82.1	26.3	358.7	313.6	83.8	80.8	325.6	188.9	146.9	164.8

TABLE 27 (continued)

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY														
COMMAND	1	3.0	203.0	2.0	319.0	3.0	759.0	2.0	795.0	2.0	1680.0	3.0	854.0	15.0	1680.0
	2	2.0	488.0	.	.	2.0	520.0	.	.	2.0	574.0	2.0	825.0	8.0	825.0
	3	2.0	161.0	.	.	.	.	.	.	.	.	.	.	2.0	161.0
	4	2.0	146.0	.	.	.	.	.	.	.	.	.	.	2.0	146.0
	ALL	9.0	488.0	2.0	319.0	5.0	759.0	2.0	795.0	4.0	1680.0	5.0	854.0	27.0	1680.0
DRIVER	DAY														
	1	3.0	652.0	2.0	87.1	3.0	365.0	2.0	136.0	2.0	420.0	2.0	291.0	14.0	652.0
	2	2.0	517.0	.	.	2.0	418.0	.	.	2.0	328.0	2.0	152.0	8.0	517.0
	3	2.0	83.5	.	.	.	.	.	.	.	.	.	.	2.0	83.5
	4	2.0	310.0	.	.	.	.	.	.	.	.	.	.	2.0	310.0
	ALL	9.0	652.0	2.0	87.1	5.0	418.0	2.0	136.0	4.0	420.0	4.0	291.0	26.0	652.0
LOADER	DAY														
	1	3.0	396.0	2.0	148.0	3.0	306.0	2.0	1010.0	2.0	871.0	3.0	599.0	15.0	1010.0
	2	2.0	321.0	.	.	2.0	329.0	.	.	2.0	342.0	2.0	607.0	8.0	607.0
	3	2.0	83.3	.	.	.	.	.	.	.	.	.	.	2.0	83.3
	4	3.0	126.0	.	.	.	.	.	.	.	.	.	.	3.0	126.0
	ALL	10.0	396.0	2.0	148.0	5.0	329.0	2.0	1010.0	4.0	871.0	5.0	607.0	28.0	1010.0
ALL	DAY														
	1	9.0	652.0	6.0	319.0	9.0	759.0	6.0	1010.0	6.0	1680.0	8.0	854.0	44.0	1680.0
	2	6.0	517.0	.	.	6.0	520.0	.	.	6.0	574.0	6.0	825.0	24.0	825.0
	3	6.0	161.0	.	.	.	.	.	.	.	.	.	.	6.0	161.0
	4	7.0	310.0	.	.	.	.	.	.	.	.	.	.	7.0	310.0

(CONTINUED)

TABLE 27 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	ALL	28.0	652.0	6.0	319.0	15.0	759.0	6.0	1010.0	12.0	1680.0	14.0	854.0	81.0	1680.0

TABLE 27 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE												ALL	
		SILL-M109		CARSON-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY														
COMMAND	1	154.3	42.2	196.9	172.7	490.7	232.4	494.5	425.0	1093.0	830.1	527.7	307.6	472.5	417.2
	2	478.5	13.4	.	.	393.5	178.9	.	.	524.0	70.7	613.5	299.1	502.4	159.1
	3	121.7	55.6	.	.	.	.	.	.	.	.	.	.	121.7	55.6
	4	111.7	48.5	.	.	.	.	.	.	.	.	.	.	111.7	48.5
	ALL	209.6	157.2	196.9	172.7	451.8	194.5	494.5	425.0	808.5	582.5	562.0	268.1	428.6	344.3
DRIVER	DAY														
	1	317.7	291.7	81.4	8.0	328.7	32.6	127.0	12.7	386.5	47.4	184.1	151.1	249.8	167.1
	2	366.0	213.5	.	.	363.0	77.8	.	.	328.0	0.0	150.0	2.8	301.8	128.1
	3	76.3	10.1	.	.	.	.	.	.	.	.	.	.	76.3	10.1
	4	218.5	129.4	.	.	.	.	.	.	.	.	.	.	218.5	129.4
	ALL	252.7	204.8	81.4	8.0	342.4	49.0	127.0	12.7	357.3	43.5	167.1	89.5	250.0	152.1
LOADER	DAY														
	1	245.3	145.3	113.4	48.9	298.0	8.0	708.5	426.4	629.0	342.2	457.3	171.3	393.6	263.8
	2	284.0	52.3	.	.	289.5	55.9	.	.	308.5	47.4	495.5	157.7	344.4	116.2
	3	82.1	1.6	.	.	.	.	.	.	.	.	.	.	82.1	1.6
	4	91.3	31.5	.	.	.	.	.	.	.	.	.	.	91.3	31.5
	ALL	174.2	117.3	113.4	48.9	294.6	28.9	708.5	426.4	468.8	272.1	472.6	146.0	324.9	229.8
ALL	DAY														
	1	239.1	178.9	130.6	96.4	372.4	147.7	443.3	376.4	702.8	514.6	415.4	245.2	374.7	310.3
	2	376.2	131.7	.	.	348.7	102.6	.	.	386.8	113.2	419.7	263.2	382.8	156.8
	3	93.4	33.6	.	.	.	.	.	.	.	.	.	.	93.4	33.6
	4	133.5	83.5	.	.	.	.	.	.	.	.	.	.	133.5	83.5
	ALL	210.8	159.4	130.6	96.4	362.9	128.0	443.3	376.4	544.8	391.7	417.2	242.9	335.4	262.5

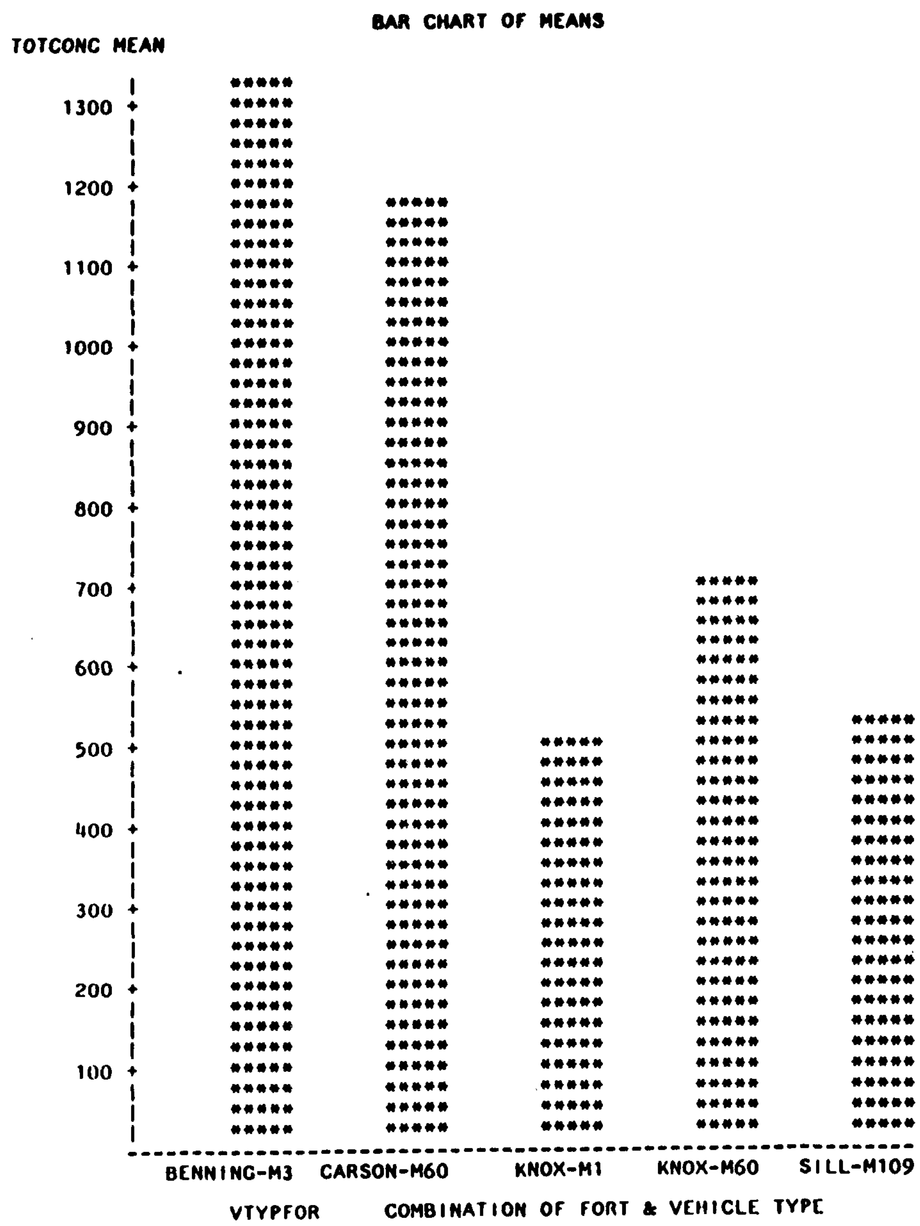


Figure 30. Concentration (TOTCONC) of total suspended particulates (ug/m^3).

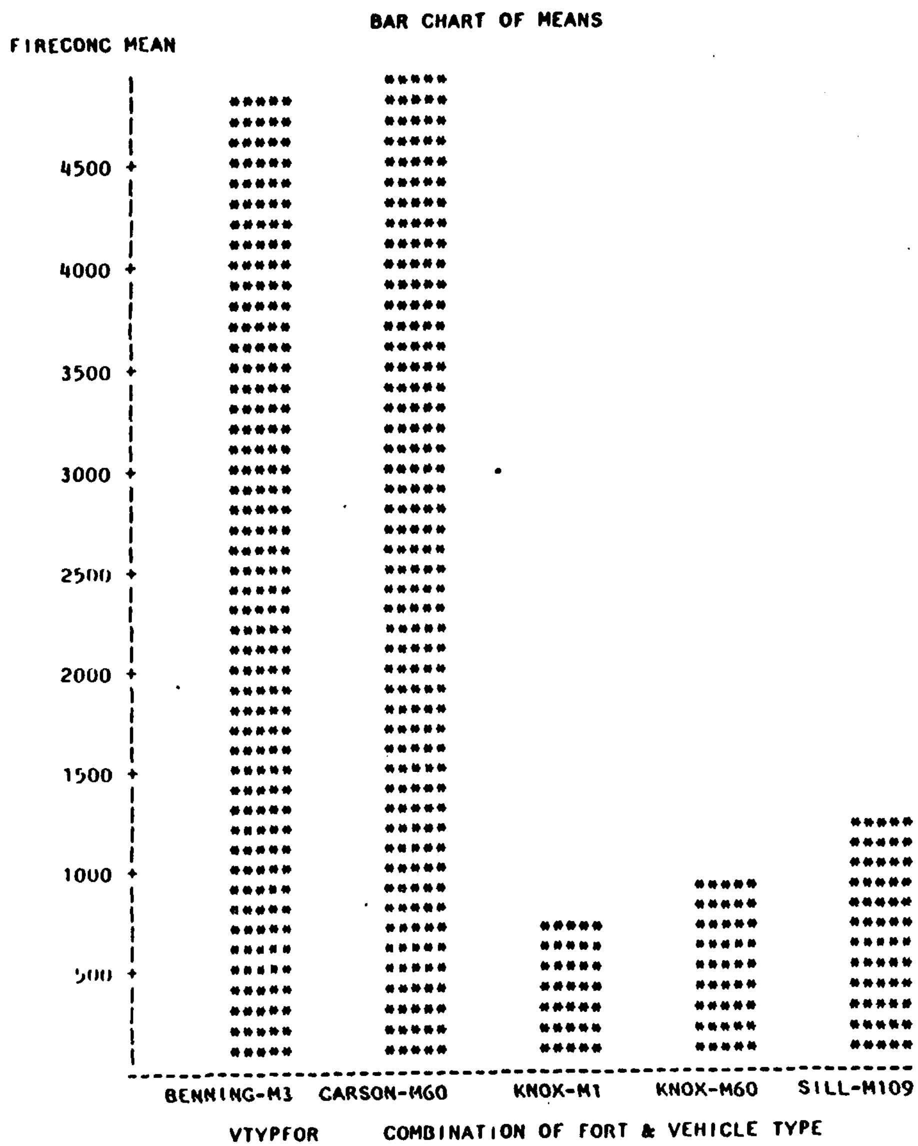


Figure 31. Concentration (FIRECONC) of total suspended particulates (ug/m^3).

TABLE 28. SUMMARY OF TOTAL SUSPENDED PARTICULATES CONCENTRATION DATA (ug/m^3)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	4.0	2050.0	4.0	348.0	4.0	774.0	4.0	2750.0	4.0	893.0	20.0	2750.0
	2	4.0	834.0	4.0	1970.0	.	.	4.0	1370.0	4.0	601.0	16.0	1970.0
	3	4.0	5150.0	.	.	.	.	.	.	.	.	4.0	5150.0
	4	4.0	409.0	.	.	.	.	.	.	.	.	4.0	409.0
	ALL	16.0	5150.0	8.0	1970.0	4.0	774.0	8.0	2750.0	8.0	893.0	44.0	5150.0
DRIVER	DAY												
	1	4.0	570.0	4.0	12400	4.0	3680.0	4.0	1210.0	4.0	436.0	20.0	12400
		4.0	915.0	4.0	1590.0	.	.	4.0	3590.0	4.0	581.0	16.0	3590.0
	3	4.0	268.0	.	.	.	.	.	.	.	.	4.0	268.0
	4	4.0	348.0	.	.	.	.	.	.	.	.	4.0	348.0
	ALL	16.0	915.0	8.0	12400	4.0	3680.0	8.0	3590.0	8.0	581.0	44.0	12400
GUNNER	DAY												
	1	.	.	.	.	1.0	374.0	2.0	739.0	2.0	1050.0	5.0	1050.0
	2	.	.	.	.	.	.	2.0	1870.0	2.0	524.0	4.0	1870.0
	ALL	.	.	.	.	1.0	374.0	4.0	1870.0	4.0	1050.0	9.0	1870.0
LOADER	DAY												
	1	4.0	295.0	4.0	714.0	4.0	625.0	4.0	2290.0	4.0	1040.0	20.0	2290.0
	2	4.0	1070.0	4.0	4090.0	.	.	4.0	1380.0	5.0	761.0	17.0	4090.0
	3	4.0	267.0	.	.	.	.	.	.	.	.	4.0	267.0
	4	4.0	334.0	.	.	.	.	.	.	.	.	4.0	334.0
	ALL	16.0	1070.0	8.0	4090.0	4.0	625.0	8.0	2290.0	9.0	1040.0	45.0	4090.0

(CONTINUED)

TABLE 28 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY												
	1	12.0	2050.0	12.0	12400	13.0	3680.0	14.0	2750.0	14.0	1050.0	65.0	12400
	2	12.0	1070.0	12.0	4090.0	.	.	14.0	3590.0	15.0	761.0	53.0	4090.0
	3	12.0	5150.0	.	.	.	.	.	.	.	.	12.0	5150.0
	4	12.0	409.0	.	.	.	.	.	.	.	.	12.0	409.0
	ALL	48.0	5150.0	24.0	12400	13.0	3680.0	28.0	3590.0	29.0	1050.0	142.0	12400

TABLE 28 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE											
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1		ALL	
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY												
COMMAND	1	779.5	858.5	318.0	20.6	450.5	222.2	1432.5	930.2	630.0	261.2	722.1	656.0
	2	698.5	163.0	1056.0	677.5	.	.	1059.0	331.0	450.0	190.6	815.9	443.6
	3	1472.5	2452.9	.	.	.	.	.	.	.	.	1472.5	2452.9
	4	305.5	81.2	.	.	.	.	.	.	.	.	305.5	81.2
	ALL	814.0	1243.3	687.0	593.7	450.5	222.2	1245.8	676.5	540.0	232.5	786.5	864.0
DRIVER	DAY												
	1	446.8	118.4	3319.0	6054.2	1285.5	1601.1	789.0	354.6	352.5	73.5	1238.5	2732.5
	2	641.8	223.5	1083.8	445.9	.	.	1742.0	1254.7	363.3	176.9	957.7	812.4
	3	185.5	63.6	.	.	.	.	.	.	.	.	185.5	63.6
	4	274.5	52.3	.	.	.	.	.	.	.	.	274.5	52.3
	ALL	387.1	235.9	2201.4	4149.9	1285.5	1601.1	1265.5	994.0	357.9	125.5	953.0	1914.5
GUNNER	DAY												
	1	.	.	.	.	374.0	.	550.0	267.3	746.5	429.2	593.4	297.7
	2	.	.	.	.	.	.	1284.0	828.7	506.5	24.7	895.3	656.2
	ALL	.	.	.	.	374.0	.	917.0	657.5	626.5	284.3	727.6	480.7
LOADER	DAY												
	1	227.0	63.5	528.8	197.6	440.3	127.2	1150.8	812.7	667.0	285.2	602.8	476.5
	2	673.8	280.8	1617.5	1678.1	.	.	1089.5	291.1	463.0	196.6	931.6	881.7
	3	175.8	69.0	.	.	.	.	.	.	.	.	175.8	69.0
	4	288.3	36.9	.	.	.	.	.	.	.	.	288.3	36.9
	ALL	341.2	242.5	1073.1	1249.9	440.3	127.2	1120.1	566.1	553.7	247.8	661.1	667.1
ALL	DAY												
	1	484.4	512.1	1388.6	3471.0	698.4	907.6	1042.1	702.9	577.9	270.6	834.4	1579.1

(CONTINUED)

TABLE 28 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC		TOTCONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ALL	DAY												
	2	671.3	207.3	1252.4	1010.1	.	.	1295.0	743.4	438.7	167.7	901.8	717.4
	3	611.3	1431.1	.	.	.	.	.	.	.	.	611.3	1431.1
	4	289.4	55.6	.	.	.	.	.	.	.	.	289.4	55.6
	ALL	514.1	757.2	1320.5	2501.0	698.4	907.6	1168.5	721.5	505.9	230.4	794.6	1229.4

TABLE 28 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
POSITION	DAY												
COMMAND	1	4.0	9000.0	4.0	2310.0	4.0	933.0	4.0	13200	4.0	1210.0	20.0	13200
	2	4.0	1710.0	4.0	2960.0	.	.	4.0	2740.0	4.0	856.0	16.0	2960.0
	3	4.0	10600	.	.	.	.	.	.	.	.	4.0	10600
	4	4.0	565.0	.	.	.	.	.	.	.	.	4.0	565.0
	ALL	16.0	10600	8.0	2960.0	4.0	933.0	8.0	13200	8.0	1210.0	44.0	13200
DRIVER	DAY												
	1	4.0	2280.0	4.0	55600	4.0	4510.0	4.0	6900.0	4.0	541.0	20.0	55600
	2	4.0	1800.0	4.0	3970.0	.	.	4.0	7190.0	4.0	827.0	16.0	7190.0
	3	4.0	600.0	.	.	.	.	.	.	.	.	4.0	600.0
	4	4.0	497.0	.	.	.	.	.	.	.	.	4.0	497.0
	ALL	16.0	2280.0	8.0	55600	4.0	4510.0	8.0	7190.0	8.0	827.0	44.0	55600
GUNNER	DAY												
	1	.	.	.	.	1.0	464.0	2.0	3750.0	2.0	1580.0	5.0	3750.0
	2	.	.	.	.	.	.	2.0	3750.0	2.0	741.0	4.0	3750.0
	ALL	.	.	.	.	1.0	464.0	4.0	3750.0	4.0	1580.0	9.0	3750.0
LOADER	DAY												
	1	4.0	1230.0	4.0	4730.0	4.0	773.0	4.0	11200	4.0	1560.0	20.0	11200
	2	4.0	2200.0	4.0	6140.0	.	.	4.0	2750.0	5.0	1080.0	17.0	6140.0
	3	4.0	586.0	.	.	.	.	.	.	.	.	4.0	586.0
	4	4.0	462.0	.	.	.	.	.	.	.	.	4.0	462.0
	ALL	16.0	2200.0	8.0	6140.0	4.0	773.0	8.0	11200	9.0	1560.0	45.0	11200

(CONTINUED)

TABLE 28 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE											
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1		ALL	
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX	# OF VEHS.	MAX
ALL	DAY												
	1	12.0	9000.0	12.0	55600	13.0	4510.0	14.0	13200	14.0	1580.0	65.0	55600
	2	12.0	2200.0	12.0	6140.0	.	.	14.0	7190.0	15.0	1080.0	53.0	7190.0
	3	12.0	10600	.	.	.	.	.	.	.	.	12.0	10600
	4	12.0	565.0	.	.	.	.	.	.	.	.	12.0	565.0
	ALL	48.0	10600	24.0	55600	13.0	4510.0	28.0	13200	29.0	1580.0	142.0	55600

TABLE 28 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENN' G-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
POSITION	DAY												
COMMAND	1	3098.3	3995.3	1780.0	483.5	557.3	258.4	9100.0	3290.8	869.3	335.7	3080.9	3827.5
	2	1311.5	376.7	2560.0	548.5	.	.	2600.0	111.7	639.3	271.8	1777.7	923.5
	3	3185.5	4951.9	.	.	.	.	.	.	.	.	3185.5	4951.9
	4	428.5	105.6	.	.	.	.	.	.	.	.	428.5	105.6
	ALL	2005.9	3099.8	2170.0	634.8	557.3	258.4	5850.0	4088.7	754.3	308.4	2375.4	3043.1
DRIVER	DAY												
	1	1546.5	824.1	15045	27037	1589.0	1953.0	5220.0	1340.0	490.5	91.8	4778.2	12118
	2	1196.3	438.7	2907.5	895.0	.	.	4090.0	2079.3	515.5	252.2	2177.3	1785.2
	3	480.5	130.0	.	.	.	.	.	.	.	.	480.5	130.0
	4	387.3	75.7	.	.	.	.	.	.	.	.	387.3	75.7
	ALL	902.6	656.3	8976.3	18860	1589.0	1953.0	4655.0	1728.4	503.0	176.2	3042.5	8303.6
GUNNER	DAY												
	1	.	.	.	.	464.0	.	3575.0	247.5	1062.5	731.9	1947.8	1554.2
	2	.	.	.	.	.	.	3010.0	1046.5	718.5	31.8	1864.3	1454.6
	ALL	.	.	.	.	464.0	.	3292.5	701.3	890.5	467.2	1910.7	1415.3
LOADER	DAY												
	1	779.0	423.8	2812.5	1447.4	550.3	154.1	7105.0	2963.4	939.0	447.6	2437.1	2863.4
	2	1281.5	628.0	3465.0	1880.3	.	.	2705.0	66.1	656.2	278.9	1946.3	1452.0
	3	439.3	98.0	.	.	.	.	.	.	.	.	439.3	98.0
	4	407.0	52.1	.	.	.	.	.	.	.	.	407.0	52.1
	ALL	726.7	499.4	3138.8	1592.1	550.3	154.1	4905.0	3049.1	781.9	369.1	1893.7	2199.2
ALL	DAY												
	1	1807.9	2367.1	6545.8	15479	865.4	1108.6	6632.1	2989.8	808.6	403.5	3317.9	7183.7

(CONTINUED)

TABLE 28 (continued)

ALL

		COMBINATION OF FORT & VEHICLE TYPE										ALL	
		SILL-M109		BENNING-M3		KNOX-M60		CARSON-M60		KNOX-M1			
		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC		FIRECONC	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ALL	DAY												
	2	1263.1	448.7	2977.5	1190.1	.	.	3114.3	1230.2	622.5	238.4	1958.9	1400.6
	3	1368.4	2914.8	.	.	.	.	.	.	.	.	1368.4	2914.8
	4	407.6	75.2	.	.	.	.	.	.	.	.	407.6	75.2
	ALL	1211.8	1900.3	4761.7	10890	865.4	1108.6	4873.2	2870.7	712.3	336.1	2400.0	5069.5

TABLE 29. SUMMARY OF ALDEHYDES CONCENTRATION DATA (ug/m^3)

LABNO	FLDCODE	ACETAL (UG/M3)	ACROLEIN (UG/M3)	CROTONAL (UG/M3)	BUTYRAL (UG/M3)	BENZAL (UG/M3)	HEXANAL (UG/M3)	TOTCAL (NO.)	TOTMASS (KG)
1101	PSM12AGALD	8.79E+01	< 1.00E+00	2.17E+00	8.83E+00	2.28E+00	< 1.28E+00	16	192.00
1102	PSM13ACALD	< 7.77E-01	< 1.00E+00	< 7.77E-01	< 2.05E+00	< 1.67E+00	< 1.28E+00	16	192.00
1103	PSM13ADALD	1.09E+00	< 1.09E+00	< 8.44E-01	< 2.23E+00	< 1.81E+00	< 1.39E+00	16	192.00
1104	PSM13ALALD	< 7.46E-01	< 9.60E-01	< 7.46E-01	< 1.97E+00	< 1.60E+00	< 1.23E+00	16	192.00
1105	PSM13AGALD	8.76E+01	< 9.60E-01	1.60E+00	9.76E+00	4.37E+00	< 1.23E+00	16	192.00
1106	PSM14ACALD	< 8.26E-01	< 1.06E+00	< 8.26E-01	< 2.18E+00	< 1.77E+00	< 1.36E+00	16	192.00
1107	PSM14ADALD	5.26E+00	< 1.25E+00	< 9.70E-01	< 2.56E+00	< 2.08E+00	< 1.59E+00	16	192.00
1108	PSM14ALALD	< 8.81E-01	< 1.13E+00	< 8.81E-01	< 2.33E+00	< 1.89E+00	< 1.45E+00	16	192.00
1109	PSM14AGALD	6.38E+00	< 1.13E+00	< 8.75E-01	< 2.31E+00	< 1.88E+00	< 1.44E+00	16	192.00
1110	PSM21ACALD	< 6.74E-01	< 8.66E-01	< 6.74E-01	< 1.78E+00	< 1.44E+00	< 1.11E+00	16	192.00
1111	PSM21ADALD	< 7.53E-01	< 9.68E-01	< 7.53E-01	< 1.99E+00	< 1.61E+00	< 1.24E+00	16	192.00
1112	PSM21ALALD	< 6.05E-01	< 7.77E-01	< 6.05E-01	< 1.60E+00	< 1.30E+00	< 9.93E-01	16	192.00
1113	PSM21AGALD	6.18E+01	< 1.05E+00	1.05E+00	1.78E+01	1.32E+01	2.58E+00	16	192.00
1114	PSM22ACALD	1.23E+00	< 9.24E-01	< 7.19E-01	< 1.90E+00	< 1.54E+00	< 1.18E+00	18	216.00
1115	PSM22ADALD	8.43E-01	< 9.48E-01	< 7.37E-01	< 1.95E+00	< 1.58E+00	< 1.21E+00	18	216.00
1116	PSM22ALALD	3.01E+00	< 7.53E-01	< 5.85E-01	< 1.55E+00	< 1.25E+00	< 9.62E-01	18	216.00
1200	FSM11AGALD	< 4.18E-01	< 3.34E-01	< 5.85E-01	< 7.11E-01	< 9.20E-01	< 7.94E-01	18	216.00
1202	FSM13ACALD	5.19E+00	< 4.19E-01	< 7.33E-01	< 8.91E-01	< 1.15E+00	< 9.95E-01	12	144.00
1203	FSM13ADALD	3.46E+01	< 4.19E-01	< 7.33E-01	< 8.91E-01	< 1.15E+00	< 9.95E-01	12	144.00
1205	FSM13ALALD	1.13E+01	< 4.31E-01	< 7.54E-01	< 9.16E-01	< 1.19E+00	< 1.02E+00	12	144.00
1206	FSM14ACALD	1.48E+01	< 9.11E-01	< 1.60E+00	< 1.94E+00	< 2.51E+00	< 2.16E+00	16	192.00
1207	FSM14ADALD	2.37E+00	< 1.00E+00	< 1.75E+00	< 2.12E+00	< 2.75E+00	< 2.37E+00	16	192.00
1209	FSM14ALALD	3.12E+01	< 8.91E-01	< 1.56E+00	< 1.89E+00	3.79E+00	< 2.12E+00	16	192.00
1211	FSM21ACALD	1.47E+01	< 9.79E-01	< 1.71E+00	< 2.08E+00	< 2.69E+00	< 2.32E+00	10	120.00
1212	FSM21ADALD	1.18E+01	< 1.05E+00	< 1.83E+00	< 2.22E+00	< 2.88E+00	< 2.48E+00	10	120.00
1214	FSM21ALALD	8.49E+00	< 1.10E+00	< 1.92E+00	< 2.33E+00	< 3.01E+00	< 2.60E+00	10	120.00
1215	FSM22ACALD	< 1.50E+00	1.80E+00	< 2.10E+00	< 2.55E+00	< 3.30E+00	< 2.85E+00	8	96.00
1216	FSM22ADALD	5.20E+00	1.85E+00	< 2.35E+00	< 2.85E+00	< 3.69E+00	< 3.19E+00	8	96.00
1218	FSM22ALALD	3.02E+00	< 1.10E+00	< 1.92E+00	< 2.34E+00	< 3.02E+00	< 2.61E+00	8	96.00
1221	FSM25ACALD	1.72E+01	< 1.25E+00	< 2.18E+00	< 2.65E+00	< 3.43E+00	< 2.97E+00	8	96.00
1222	FSM25ADALD	< 1.53E+00	< 1.22E+00	< 2.14E+00	< 2.59E+00	< 3.36E+00	< 2.90E+00	8	96.00
1224	FSM25ALALD	4.24E+02	< 1.26E+00	4.55E+00	< 2.67E+00	3.77E+00	< 2.98E+00	8	96.00
1302	FBB13ACALD	< 2.09E+00	< 1.67E+00	< 2.93E+00	< 3.56E+00	< 4.60E+00	< 3.97E+00	239	5.08
1303	FBB13ADALD	3.62E+01	< 1.71E+00	< 2.99E+00	7.68E+01	< 4.69E+00	< 4.05E+00	239	5.08
1305	FBB13ALALD	1.82E+01	< 1.73E+00	< 3.03E+00	< 3.67E+00	< 4.75E+00	< 4.11E+00	239	5.08
1306	FBB14ACALD	4.93E+01	< 1.68E+00	< 3.29E+00	6.34E+01	6.10E+00	4.69E+00	424	10.00
1307	FBB14ADALD	3.73E+01	< 1.66E+00	< 2.90E+00	7.68E+01	< 4.56E+00	< 3.94E+00	424	10.00
1309	FBB14ALALD	1.77E+01	< 1.63E+00	< 2.85E+00	< 3.46E+00	< 4.47E+00	< 3.88E+00	424	10.00

TABLE 29 (continued)

LABNO	FLDCODE	ACETAL (UG/M3)	ACROLEIN (UG/M3)	CROTONAL (UG/M3)	BUTYRAL (UG/M3)	BENZAL (UG/M3) *	HEXANAL (UG/M3)	TOTCAL (NO.)	TOTMASS (KG)
1311	FBB21ACALD	2.55E+01	< 1.20E+00	< 2.10E+00	1.95E+02	4.65E+00	3.00E+00	467	12.75
1312	FBB21ADALD	1.63E+00	< 1.19E+00	< 2.08E+00	< 2.52E+00	< 3.26E+00	< 2.82E+00	467	12.75
1314	FBB21ALALD	7.17E+00	< 1.15E+00	< 2.01E+00	< 2.44E+00	4.02E+00	< 2.72E+00	467	12.75
1315	FBB22ACALD	5.98E+00	< 1.09E+00	< 1.90E+00	< 2.31E+00	< 2.99E+00	< 2.58E+00	463	12.35
1316	FBB22ADALD	< 1.45E+00	< 1.16E+00	< 2.03E+00	< 2.47E+00	< 3.19E+00	< 2.76E+00	463	12.35
1318	FBB22ALALD	< 1.46E+00	< 1.17E+00	< 2.04E+00	1.08E+01	< 3.20E+00	< 2.77E+00	463	12.35
1321	FBB25ACALD	4.15E+00	< 1.07E+00	< 1.87E+00	< 2.27E+00	< 2.94E+00	< 2.54E+00	382	11.53
1322	FBB25ADALD	< 1.32E+00	< 1.06E+00	< 1.85E+00	< 2.24E+00	< 2.90E+00	< 2.51E+00	382	11.53
1324	FBB25ALALD	7.69E+00	< 1.06E+00	< 1.86E+00	< 2.25E+00	< 2.92E+00	< 2.52E+00	382	11.53
1502	FCT13ACALD	2.27E+01	< 1.10E+01	< 8.59E+00	< 1.29E+01	< 1.59E+01	2.39E+01	160	58.50
1503	FCT13ADALD	3.79E+01	< 1.00E+01	< 7.80E+00	< 1.17E+01	< 1.45E+01	1.62E+01	160	58.50
1505	FCT13ALALD	3.08E+01	< 9.90E+00	< 7.70E+00	< 1.16E+01	< 1.43E+01	1.76E+01	160	58.50
1506	FCT14ACALD	4.54E+01	< 1.10E+01	< 8.59E+00	< 1.29E+01	< 1.59E+01	5.70E+01	163	75.60
1507	FCT14ADALD	9.99E+01	< 1.06E+01	< 8.22E+00	< 1.23E+01	< 1.53E+01	6.46E+01	163	75.60
1509	FCT14ALALD	5.60E+01	< 1.01E+01	< 7.83E+00	2.41E+01	< 1.45E+01	6.71E+01	163	75.60
1511	FCT21ACALD	2.25E+01	< 1.04E+01	< 8.09E+00	< 1.21E+01	< 1.50E+01	< 1.62E+01	162	69.90
1512	FCT21ADALD	3.42E+01	< 1.14E+01	< 8.86E+00	< 1.33E+01	< 1.65E+01	< 1.77E+01	162	69.90
1513	FCT21AGALD	3.09E+01	< 1.11E+01	< 8.65E+00	< 1.30E+01	< 1.61E+01	< 1.73E+01	162	69.90
1514	FCT21ALALD	3.81E+01	< 1.04E+01	< 8.09E+00	< 1.21E+01	< 1.50E+01	< 1.62E+01	162	69.90
1515	FCT22ACALD	2.34E+01	< 9.79E+00	< 7.62E+00	< 1.14E+01	< 1.41E+01	< 1.52E+01	166	92.70
1518	FCT22ALALD	1.94E+01	< 9.44E+00	< 7.34E+00	< 1.10E+01	< 1.36E+01	< 1.47E+01	166	92.70
1522	FCT25ADALD	9.16E+00	< 3.36E+00	< 2.62E+00	< 3.92E+00	8.41E+00	3.36E+01	160	58.50
1524	FCT25ALALD	3.20E+01	< 4.43E+00	< 3.45E+00	1.13E+01	9.11E+00	5.60E+01	160	58.50
1602	FKA13ACALD	2.00E+00	< 1.20E+00	< 1.12E+00	1.44E+00	8.81E-01	1.84E+00	272	126.15
1603	FKA13ADALD	1.76E+00	1.47E+00	< 1.03E+00	< 8.06E-01	1.47E+00	3.37E+00	272	126.15
1605	FKA13ALALD	2.47E+00	1.67E+00	< 9.35E-01	< 7.34E-01	1.07E+00	2.67E+00	272	126.15
1606	FKA14ACALD	2.28E+00	1.22E+00	< 7.43E-01	1.01E+00	7.43E-01	1.75E+00	118	102.90
1607	FKA14ADALD	1.27E+00	9.55E-01	< 7.43E-01	< 5.84E-01	< 4.78E-01	< 9.55E-01	118	102.90
1609	FKA14ALALD	1.59E+00	< 9.02E-01	< 7.43E-01	8.49E-01	5.84E-01	< 9.55E-01	118	102.90
1611	FKA21ACALD	2.03E+00	< 7,94E-01	< 6.94E-01	< 5.46E-01	4.96E-01	1.24E+00	178	160.05
1612	FKA21ADALD	2.55E+00	9.66E-01	< 6.15E-01	< 4.83E-01	7.47E-01	1.71E+00	178	160.05
1614	FKA21ALALD	2.01E+00	< 7.49E-01	< 6.56E-01	< 5.15E-01	< 4.22E+00	1.12E+00	178	160.05
1615	FKA22ACALD	2.71E+00	8.53E-01	< 4.27E-01	7.62E-01	5.79E-01	1.16E+00	124	137.10
1616	FKA22ADALD	1.27E+00	7.00E-01	< 4.67E-01	< 3.67E-01	< 3.00E-01	< 6.00E-01	124	137.10
1618	FKA22ALALD	9.99E-01	5.80E-01	< 4.51E-01	< 3.54E-01	< 2.90E-01	< 5.80E-01	124	137.10
1624	FKA25ALALD	1.83E+00	< 5.00E-01	< 4.67E-01	< 3.67E-01	5.33E-01	1.50E+00	132	142.10
1702	FKT13ACALD	4.28E+00	< 2.83E-01	< 4.95E-01	< 3.89E-01	9.19E-01	1.84E+00	331	177.60
1703	FKT13ADALD	< 7.11E-01	< 1.14E+00	< 9.95E-01	< 7.82E-01	9.24E-01	< 1.28E+00	331	177.60

TABLE 29 (continued)

LABNO	FLDCODE	ACETAL (UG/M3)	ACROLEIN (UG/M3)	CROTONAL (UG/M3)	BUTYRAL (UG/M3)	BENZAL (UG/M3)	HEXANAL (UG/M3)	TOTCAL (NO.)	TOTMASS (KG)
1704	FKT13AGALD	7.74E+00	1.56E+00	< 9.95E-01	< 7.82E-01	1.56E+00	2.06E+00	331	177.60
1705	FKT13ALALD	4.05E+00	< 6.39E-01	< 4.97E-01	< 3.91E-01	9.59E-01	1.49E+00	331	177.60
1706	FKT14ACALD	3.59E+00	6.09E-01	< 4.26E-01	< 3.35E-01	9.74E-01	1.73E+00	577	155.55
1707	FKT14ADALD	4.94E+00	1.02E+00	< 4.22E-01	3.61E-01	1.05E+00	1.51E+00	577	155.55

TABLE 30. CONCENTRATION (FIRECONC) DATA FOR POLYCYCLIC AROMATIC HYDROCARBONS (ug/m^3)

LABNO	FLDCODE	NAPHTHALENE (UG/M3)	ACENAPHTHENE (UG/M3)	PYRENE (UG/M3)	TOTCAL (NO.)	TOTMASS (KG)
13100	PSM11ACPAH	< 2.95E+01	< 2.75E+01	< 3.22E+01	12	144.00
13101	PSM11ADPAH	< 2.52E+01	< 2.35E+01	< 2.75E+01	12	144.00
13102	PSM11ALPAH	2.78E+01	< 2.34E+01	< 2.74E+01	12	144.00
13104	PSM11BCPAH	< 2.16E+01	< 2.02E+01	< 2.37E+01	12	144.00
13105	PSM11BDPAH	< 2.58E+01	< 2.41E+01	< 2.82E+01	12	144.00
13106	PSM11BLPAH	< 2.61E+01	< 2.44E+01	< 2.85E+01	12	144.00
13107	PSM12ACPAH	3.29E+01	< 2.77E+01	< 3.24E+01	16	192.00
13108	PSM12ADPAH	< 3.15E+01	< 2.94E+01	< 3.44E+01	16	192.00
13109	PSM12ALPAH	2.33E+01	< 1.96E+01	< 2.29E+01	16	192.00
13111	PSM12BCPAH	< 2.32E+01	< 2.17E+01	< 2.54E+01	16	192.00
13112	PSM12BDPAH	< 2.52E+01	< 2.35E+01	< 2.75E+01	16	192.00
13113	PSM12BLPAH	< 2.52E+01	< 2.35E+01	< 2.75E+01	16	192.00
13118	PSM23ACPAH	< 6.36E+01	< 5.94E+01	< 6.96E+01	17	204.00
13119	PSM23ADPAH	< 6.36E+01	< 5.94E+01	< 6.96E+01	17	204.00
13120	PSM23ALPAH	< 2.89E+01	< 2.70E+01	< 3.16E+01	17	204.00
13122	PSM23BCPAH	< 2.19E+01	< 2.05E+01	< 2.40E+01	17	204.00
13123	PSM23BDPAH	< 2.96E+01	< 2.76E+01	< 3.24E+01	17	204.00
13124	PSM23BLPAH	< 3.10E+01	< 2.90E+01	< 3.39E+01	17	204.00
13125	PSM24ACPAH	< 4.65E+01	4.34E+01	< 5.08E+01	16	192.00
13126	PSM24ADPAH	2.58E+01	< 2.17E+01	< 2.54E+01	16	192.00
13129	PSM24BCPAH	< 2.43E+01	< 2.26E+01	< 2.65E+01	16	192.00
13130	PSM24BDPAH	< 2.11E+01	< 1.97E+01	< 2.31E+01	16	192.00
13131	PSM24BLPAH	< 2.54E+01	< 2.37E+01	< 2.77E+01	16	192.00
13200	FSM11ACPAH	< 1.60E+01	< 2.17E+01	< 6.26E+00	7	84.00
13201	FSM11ADPAH	2.16E+01	< 1.76E+01	< 5.20E+00	7	84.00
13203	FSM11ALPAH	< 1.42E+01	< 1.84E+01	< 5.42E+00	7	84.00
13204	FSM11BCPAH	< 1.44E+01	< 1.94E+01	< 5.62E+00	7	84.00
13205	FSM11BDPAH	< 2.95E+01	< 3.99E+01	< 1.15E+01	7	84.00
13206	FSM11BLPAH	< 1.42E+01	< 1.91E+01	< 5.53E+00	7	84.00
13208	FSM12ADPAH	1.32E+01	< 1.61E+01	1.03E+01	12	144.00
13210	FSM12ALPAH	1.48E+01	< 1.62E+01	7.38E+00	12	144.00
13212	FSM12BDPAH	< 1.71E+01	< 2.30E+01	< 6.66E+00	12	144.00
13213	FSM12BLPAH	< 1.71E+01	< 2.30E+01	< 6.66E+00	12	144.00
13219	FSM15ALPAH	< 1.42E+01	< 1.91E+01	< 5.52E+00	13	156.00
13220	FSM15BCPAH	< 1.42E+01	< 1.91E+01	< 5.52E+00	13	156.00
13221	FSM15BDPAH	< 1.49E+01	< 2.01E+01	< 5.81E+00	13	156.00
13222	FSM15BLPAH	< 1.45E+01	< 1.96E+01	< 5.66E+00	13	156.00
13300	FBB11ACPAH	< 4.75E+01	< 8.05E+01	< 1.84E+01	490	10.20
13301	FBB11ADPAH	< 4.75E+01	< 8.05E+01	< 1.84E+01	490	10.20

TABLE 30 (continued)

LABNO	FLDCODE	NAPHTHALENE (UG/M3)	ACENAPHTHENE (UG/M3)	PYRENE (UG/M3)	TOTCAL (NO.)	TOTMASS (KG)
13303	FBB11ALPAH	< 4.72E+01	< 8.01E+01	< 1.83E+01	490	10.20
13304	FBB11BCPAH	6.15E+01	< 7.99E+01	< 1.82E+01	490	10.20
13306	FBB11BLPAH	< 4.57E+01	< 7.76E+01	< 1.77E+01	490	10.20
13307	FBB12ACPAH	< 4.87E+01	< 8.25E+01	< 1.88E+01	411	9.96
13308	FBB12ADPAH	< 5.09E+01	< 8.63E+01	< 1.97E+01	411	9.96
13310	FBB12ALPAH	< 4.36E+01	< 7.39E+01	< 1.69E+01	411	9.96
13312	FBB12BDPAH	< 4.31E+01	< 7.30E+01	< 1.67E+01	411	9.96
13313	FBB12BLPAH	< 3.94E+01	< 6.68E+01	< 1.52E+01	411	9.96
13316	FBB15ACPAH	< 5.27E+01	< 8.94E+01	< 2.04E+01	487	13.10
13317	FBB15ADPAH	< 5.14E+01	< 8.71E+01	< 1.99E+01	487	13.10
13319	FBB15ALPAH	< 5.08E+01	< 8.62E+01	< 1.97E+01	487	13.10
13320	FBB15BCPAH	< 5.14E+01	< 8.71E+01	< 1.99E+01	487	13.10
13321	FBB15BDPAH	< 5.14E+01	< 8.71E+01	< 1.99E+01	487	13.10
13325	FBB23ACPAH	< 3.12E+01	< 5.29E+01	< 1.21E+01	206	6.05
13326	FBB23ADPAH	< 3.10E+01	< 5.26E+01	< 1.20E+01	206	6.05
13331	FBB23BLPAH	< 2.97E+01	< 5.03E+01	< 1.15E+01	206	6.05
13333	FBB24ADPAH	< 3.42E+01	< 5.80E+01	< 1.32E+01	329	12.05
13335	FBB24ALPAH	< 3.25E+01	< 5.51E+01	< 1.26E+01	329	12.05
13336	FBB24BCPAH	< 3.49E+01	< 5.92E+01	< 1.35E+01	329	12.05
13337	FBB24BDPAH	< 3.39E+01	< 5.75E+01	< 1.31E+01	329	12.05
13338	FBB24BLPAH	< 2.66E+01	< 4.51E+01	< 1.03E+01	329	12.05
13400	FCM11ACPAH	< 2.90E+01	1.26E+02	< 1.12E+01	12	144.00
13401	FCM11ADPAH	< 2.47E+01	4.19E+02	< 9.57E+00	12	144.00
13403	FCM11ALPAH	< 2.63E+01	2.06E+02	< 1.02E+01	12	144.00
13404	FCM11BCPAH	< 2.84E+01	< 4.82E+01	< 1.10E+01	12	144.00
13405	FCM11BDPAH	< 3.26E+01	< 5.30E+01	< 1.21E+01	12	144.00
13407	FCM11BLPAH	< 3.24E+01	6.76E+01	< 1.20E+01	12	144.00
13408	FCM12ACPAH	< 2.36E+01	1.74E+02	< 9.12E+00	2	24.00
13409	FCM12ADPAH	3.70E+01	5.81E+02	< 9.40E+00	2	24.00
13411	FCM12ALPAH	< 2.20E+01	2.93E+02	< 8.15E+00	2	24.00
13412	FCM12BCPAH	< 2.36E+01	9.26E+01	< 8.77E+00	2	24.00
13413	FCM12BDPAH	< 2.40E+01	1.60E+02	< 8.90E+00	2	24.00
13415	FCM12BLPAH	< 2.27E+01	9.46E+01	< 8.42E+00	2	24.00
13500	FCT11ACPAH	< 9.99E+01	4.58E+02	< 3.71E+01	161	64.20
13501	FCT11ADPAH	< 1.00E+02	6.70E+02	< 3.73E+01	161	64.20
13503	FCT11ALPAH	< 8.97E+01	< 1.52E+02	< 3.47E+01	161	64.20
13507	FCT12ACPAH	< 9.80E+01	< 1.59E+02	< 3.63E+01	117	69.45
13508	FCT12ADPAH	< 1.05E+02	5.70E+02	< 3.90E+01	117	69.45
13510	FCT12ALPAH	< 1.16E+02	< 1.88E+02	< 4.29E+01	117	69.45

TABLE 30 (continued)

LABNO	FLDCODE	NAPHTHALENE (UG/M3)	ACENAPHTHENE (UG/M3)	PYRENE (UG/M3)	TOTCAL (NO.)	TOTMASS (KG)
13511	FCT12BCPAH	< 1.15E+02	< 1.86E+02	< 4.25E+01	117	69.45
13512	FCT12BDPAH	< 1.09E+02	< 1.78E+02	< 4.06E+01	117	69.45
13513	FCT12BLPAH	< 1.13E+02	< 1.84E+02	< 4.20E+01	117	69.45
13516	FCT15ACPAH	< 8.05E+01	< 1.31E+02	< 2.99E+01	156	35.70
13519	FCT15ALPAH	< 7.97E+01	< 1.30E+02	< 2.96E+01	156	35.70
13525	FCT23ACPAH	< 9.64E+01	< 1.57E+02	< 3.57E+01	161	64.20
13526	FCT23ADPAH	< 9.30E+01	< 1.51E+02	< 3.45E+01	161	64.20
13528	FCT23ALPAH	< 9.12E+01	< 1.55E+02	< 3.53E+01	161	64.20
13529	FCT23BCPAH	< 9.65E+01	< 1.57E+02	< 3.58E+01	161	64.20
13530	FCT23BDPAH	< 1.10E+02	2.02E+02	< 4.08E+01	161	64.20
13531	FCT23BLPAH	< 9.77E+01	< 1.59E+02	< 3.62E+01	161	64.20
13532	FCT24ACPAH	1.25E+02	1.73E+03	< 3.58E+01	156	35.70
13533	FCT24ADPAH	9.27E+01	1.05E+03	< 3.59E+01	156	35.70
13535	FCT24ALPAH	< 1.08E+02	< 1.76E+02	< 4.01E+01	156	35.70
13536	FCT24BCPAH	< 9.53E+01	< 1.55E+02	< 3.53E+01	156	35.70
13537	FCT24BDPAH	< 9.84E+01	< 1.67E+02	< 3.81E+01	156	35.70
13538	FCT24BLPAH	< 1.06E+02	< 1.72E+02	< 3.92E+01	156	35.70
13540	FCT11BGPAH	< 9.90E+01	< 1.61E+02	< 3.67E+01	161	64.20
13541	FCT12BGPAH	< 8.02E+01	< 1.30E+02	< 2.97E+01	117	69.45
13542	FCT23BGPAH	< 9.65E+01	< 1.57E+02	< 3.58E+01	161	64.20
13543	FCT24BGPAH	9.75E+01	1.61E+03	< 3.77E+01	156	35.70
13600	FKA11ACPAH	5.33E+00	1.54E+01	< 2.54E+00	215	86.10
13601	FKA11ADPAH	1.05E+01	< 8.33E+00	< 2.31E+00	215	86.10
13605	FKA11BDPAH	4.21E+00	1.25E+01	< 2.08E+00	215	86.10
13606	FKA11BGPAH	5.58E+00	< 9.16E+00	< 2.54E+00	215	86.10
13607	FKA11BLPAH	4.98E+00	3.09E+01	< 2.62E+00	215	86.10
13608	FKA12ACPAH	8.17E+00	2.12E+01	1.01E+01	51	119.79
13609	FKA12ADPAH	9.54E+00	3.79E+01	< 2.73E+00	51	119.79
13611	FKA12ALPAH	1.04E+01	1.82E+01	1.07E+01	51	119.79
13612	FKA12BCPAH	7.27E+00	2.45E+01	< 2.42E+00	51	119.79
13613	FKA12BDPAH	6.96E+00	3.45E+01	< 2.79E+00	51	119.79
13614	FKA12BGPAH	7.91E+00	4.91E+01	< 2.93E+00	51	119.79
13615	FKA12BLPAH	6.92E+00	1.65E+02	< 2.55E+00	51	119.79
13624	FKA23ACPAH	3.83E+00	2.71E+01	< 1.78E+00	125	142.80
13625	FKA23ADPAH	< 3.01E+00	5.18E+01	< 1.78E+00	125	142.80
13627	FKA23ALPAH	< 2.41E+00	1.58E+01	< 1.42E+00	125	142.80
13628	FKA23BCPAH	< 3.17E+00	3.03E+01	< 1.87E+00	125	142.80
13630	FKA23BGPAH	3.80E+00	1.94E+01	< 1.78E+00	125	142.80
13631	FKA23BLPAH	< 2.87E+00	2.96E+01	< 1.69E+00	125	142.80

TABLE 30 (continued)

LABNO	FLDCODE	NAPHTHALENE (UG/M3)	ACENAPHTHENE (UG/M3)	PYRENE (UG/M3)	TOTCAL (NO.)	TOTMASS (KG)
13632	FKA24ACPAH	6.36E+00	2.40E+01	1.42E+01	30	171.00
13633	FKA24ADPAH	4.39E+00	3.75E+01	< 1.59E+00	30	171.00
13635	FKA24ALPAH	7.30E+00	2.30E+01	3.33E+00	30	171.00
13636	FKA24BCPAH	4.92E+00	< 5.52E+00	< 1.53E+00	30	171.00
13637	FKA24BDPAH	4.48E+00	< 6.31E+00	< 1.75E+00	30	171.00
13638	FKA24BGPAH	6.37E+00	< 6.62E+00	< 1.83E+00	30	171.00
13639	FKA24BLPAH	6.69E+00	< 5.76E+00	< 1.59E+00	30	171.00
13700	FKT11ACPAH	6.10E+00	< 3.91E+00	2.40E+00	552	155.48
13701	FKT11ADPAH	2.51E+01	< 4.26E+00	< 1.18E+00	552	155.48
13703	FKT11ALPAH	7.50E+00	< 4.00E+00	2.24E+00	552	155.48
13704	FKT11BCPAH	4.55E+00	< 3.87E+00	< 1.07E+00	552	155.48
13705	FKT11BDPAH	9.78E+00	< 3.65E+00	< 1.01E+00	552	155.48
13706	FKT11BGPAH	4.55E+00	< 4.35E+00	< 1.21E+00	552	155.48
13707	FKT11BLPAH	6.05E+00	< 4.02E+00	< 1.11E+00	552	155.48
13708	FKT12ACPAH	4.68E+00	< 4.51E+00	1.59E+00	327	154.80
13711	FKT12ALPAH	5.86E+00	< 3.61E+00	1.64E+00	327	154.80
13712	FKT12BCPAH	5.06E+00	< 3.55E+00	1.19E+00	327	154.80
13713	FKT12BDPAH	9.98E+00	< 4.60E+00	< 1.27E+00	327	154.80
13714	FKT12BGPAH	0.00E+00	< 4.22E+00	< 1.17E+00	327	154.80
13715	FKT12BLPAH	0.00E+00	< 8.48E+00	< 2.35E+00	327	154.80

TABLE 31. METALS

Element	Code	Approximate Detection Limit ($\mu g/m^3$)
Silver	Ag	0.3
*Aluminum	Al	1
Arsenic	As	0.1
Barium	Ba	0.3
Beryllium	Be	0.03
*Calcium	Ca	1
Cadmium	Cd	1
Cobalt	Co	3
*Chromium	Cr	1
*Copper	Cu	0.7
*Iron	Fe	1
Mercury	Hg	0.01
Potassium	K	30
*Magnesium	Mg	1
Manganese	Mn	1
Molybdenum	Mo	10
Sodium	Na	30
Nickel	Ni	3
Phosphorus	P	30
Lead	Pb	6
*Antimony	Sb	0.1
Selenium	Se	0.1
*Strontium	Sr	0.07
Thallium	Th	3
*Titanium	Ti	0.3
Vanadium	V	0.3
*Zinc	Zn	1
Zirconium	Zr	3

TABLE 32. METAL CONCENTRATION RANGES ($\mu g/m^3$)

Element	Mean Range	Maximum	TLV*
Al	5.0 - 188	648	N/A
Ca	22 - 633	1710	N/A
Cr	1.9 - 16.3	31.1	500
Cu	8.7 - 25.3	109	1000
Fe	8.6 - 21.9	1000	N/A
Mg	4.0 - 59.3	188	10,000
Sb	0.3 - 11.1	36.8	500
Sr	0.5 - 3.10	10.1	N/A
Ti	1.1 - 10.0	49.9	15,000
Zn	4.8 - 52.8	147	1000

*TLV of element or compound

TABLE 33. CONCENTRATION (FIRECONC) DATA FOR METALS (ug/L)*

17:28 WEDNESDAY, JANUARY 18, 1989 1

LABNO	FLDCODE	SCALE	FORT	VEHTYP	DAY	VEHNO	FIXBZ	AREAPRSN	ANALYTE	TSHELL	TOTMASS	AL	CA	CR
9302	FBB13ACMET	F	B	B	1	3	A	C	MET	239	5.0800	0.042500	0.12300	0.0220000
9303	FBB13ADMET	F	B	B	1	3	A	D	MET	239	5.0800	0.048100	0.14400	0.0154000
9305	FBB13ALMET	F	B	B	1	3	A	L	MET	239	5.0800	0.046200	0.00433	0.0130000
9307	FBB13BDMET	F	B	B	1	3	B	D	MET	239	5.0800	0.060600	0.09510	0.0110000
9308	FBB13BLMET	F	B	B	1	3	B	L	MET	239	5.0800	0.013300	0.19200	0.0092900
9309	FBB14ACMET	F	B	B	1	4	A	C	MET	424	10.0000	0.058200	0.07860	0.0189000
9310	FBB14ADMET	F	B	B	1	4	A	D	MET	424	10.0000	0.123000	0.15800	0.0174000
9312	FBB14ALMET	F	B	B	1	4	A	L	MET	424	10.0000	0.169000	0.05060	0.0199000
9313	FBB14BCMET	F	B	B	1	4	B	C	MET	424	10.0000	0.004670	0.05140	0.0218000
9314	FBB14BDMET	F	B	B	1	4	B	D	MET	424	10.0000	0.143000	0.11100	0.0174000
9315	FBB14BLMET	F	B	B	1	4	B	L	MET	424	10.0000	0.031400	0.21700	0.0164000
9317	FBB21ACMET	F	B	B	2	1	A	C	MET	467	12.7500	0.115000	0.23900	0.0094400
9318	FBB21ADMET	F	B	B	2	1	A	D	MET	467	12.7500	0.092800	0.34200	0.0111000
9320	FBB21ALMET	F	B	B	2	1	A	L	MET	467	12.7500	0.648000	0.20700	0.0097800
9321	FBB21BCMET	F	B	B	2	1	B	C	MET	467	12.7500	0.157000	0.09310	0.0122000
9322	FBB21BDMET	F	B	B	2	1	B	D	MET	467	12.7500	0.100000	0.07130	0.0077100
9323	FBB21BLMET	F	B	B	2	1	B	L	MET	467	12.7500	0.147000	0.20400	0.0066600
9324	FBB22ACMET	F	B	B	2	2	A	C	MET	463	12.3500	0.029500	0.01160	0.0089400
9325	FBB22ADMET	F	B	B	2	2	A	D	MET	463	12.3500	0.129000	0.23300	0.0081900

CU	E	MG	SB	SR	TI	ZN	SELECT	TREAT	VTYPFORT	VLOC	GROUP
0.0103000	0.12200	0.004390	0.0019000	0.0010300	0.0029300	0.019000	1	1	BBFV	A	NON
0.0085800	0.01200	0.005150	0.0013700	0.0008580	0.0017200	0.022300	1	2	BBFV	A	NON
0.0144000	0.02890	0.004330	0.0030300	0.0010100	0.0043300	0.027500	1	3	BBFV	A	NON
0.0110000	0.04820	0.012400	0.0023400	0.0009650	0.0055100	0.020700	1	5	BBFV	A	NON
0.0092900	0.03580	0.007970	0.0017300	0.0009290	0.0026600	0.018600	1	6	BBFV	A	NON
0.0346000	0.12600	0.012600	0.0055000	0.0028300	0.0062900	0.069200	1	1	BBFV	A	NON
0.0290000	0.19300	0.020300	0.0044900	0.0021700	0.0058000	0.052200	1	2	BBFV	A	NON
0.0169000	0.28500	0.035300	0.0035300	0.0010700	0.0107000	0.046000	1	3	BBFV	A	NON
0.0109000	0.18700	0.004670	0.0015600	0.0007790	0.0015600	0.018700	1	4	BBFV	A	NON
0.0095200	0.21400	0.025400	0.0030100	0.0015900	0.0095200	0.049200	1	5	BBFV	A	NON
0.0209000	0.06580	0.008970	0.0031400	0.0019400	0.0044800	0.046300	1	6	BBFV	A	NON
0.0198000	0.20500	0.031100	0.0037700	0.0056600	0.0084900	0.069800	1	1	BBFV	A	NON
0.0050400	0.09680	0.019200	0.0012100	0.0013100	0.0050400	0.024200	1	2	BBFV	A	NON
0.0264000	0.77800	0.188000	0.0063600	0.0088000	0.0499000	0.131000	1	3	BBFV	A	NON
0.0357000	0.30700	0.045200	0.0060000	0.0093100	0.0130000	0.125000	1	4	BBFV	A	NON
0.0077100	0.13300	0.024100	0.0022200	0.0024100	0.0077100	0.033700	1	5	BBFV	A	NON
0.0276000	0.27500	0.045700	0.0051400	0.0069500	0.0133000	0.099900	1	6	BBFV	A	NON
0.0107000	0.18700	0.005360	0.0030400	0.0034000	0.0035700	0.032200	1	1	BBFV	A	NON
0.0174000	0.24900	0.031700	0.0146000	0.0064500	0.0102000	0.104000	1	2	BBFV	A	NON

*Legend on last page of table.

TABLE 33 (continued)

LABNO	FLDCODE	SCALE	FORT	VEHTYP	DAY	VEHNO	FIXBZN	AREAPRSN	ANALYTE	TSHELL	TOTMASS	AL	CA	CR
9327	FBB22ALMET	F	B	B	2	2	A	L	MET	463	12.350	0.123000	0.04140	0.0109000
9330	FBB22BLMET	F	B	B	2	2	B	L	MET	463	12.350	0.100000	0.04140	0.0108000
9333	FBB25ACMET	F	B	B	2	5	A	C	MET	382	11.530	0.086500	0.22100	0.0112000
9334	FBB25ADMET	F	B	B	2	5	A	D	MET	382	11.530	0.088300	0.01140	0.0166000
9336	FBB25ALMET	F	B	B	2	5	A	L	MET	382	11.530	0.406000	0.18900	0.0092700
9337	FBB25BCMET	F	B	B	2	5	B	C	MET	382	11.530	0.082400	0.08830	0.0136000
9338	FBB25BDMET	F	B	B	2	5	B	D	MET	382	11.530	0.153000	0.06560	0.0114000
9339	FBB25BLMET	F	B	B	2	5	B	L	MET	382	11.530	0.080300	0.12800	0.0076900
9502	FCT13ACMET	F	C	T	1	3	A	C	MET	160	58.500	0.287000	0.52200	0.0223000
9503	FCT13ADMET	F	C	T	1	3	A	D	MET	160	58.500	0.160000	0.34300	0.0103000
9505	FCT13ALMET	F	C	T	1	3	A	L	MET	160	58.500	0.284000	1.14000	0.0235000
9506	FCT13BCMET	F	C	T	1	3	B	C	MET	160	58.500	0.077300	0.01930	0.0072500
9507	FCT13BDMET	F	C	T	1	3	B	D	MET	160	58.500	0.189000	0.61000	0.0073800
9540	FCT13BGMET	F	C	T	1	3	B	G	MET	160	58.500	0.239000	0.74700	0.0074700
9508	FCT13BLMET	F	C	T	1	3	B	L	MET	160	58.500	0.051500	0.13700	0.0073600
9509	FCT14ACMET	F	C	T	1	4	A	C	MET	163	75.600	0.284000	0.68800	0.0171000
9510	FCT14ADMET	F	C	T	1	4	A	D	MET	163	75.600	0.160000	0.68000	0.0140000
9512	FCT14ALMET	F	C	T	1	4	A	L	MET	163	75.600	0.288000	0.42900	0.0226000
9513	FCT14BCMET	F	C	T	1	4	B	C	MET	163	75.600	0.209000	0.42900	0.0102000

CU	FE	MG	SB	SR	TI	ZN	SELECT	TREAT	VTYPFORT	VLOC	GROUP
0.0316000	0.30300	0.032600	0.0264000	0.0101000	0.0109000	0.147000	1	3	BBFV	A	NON
0.0384000	0.18700	0.024600	0.0049300	0.0059100	0.0078800	0.068000	1	6	BBFV	A	NON
0.0018600	0.11500	0.020500	0.0010200	0.0012100	0.0074400	0.040000	1	1	BBFV	A	NON
0.0035000	0.15900	0.021900	0.0012200	0.0013100	0.0078700	0.038500	1	2	BBFV	A	NON
0.0018500	0.49600	0.151000	0.0010200	0.0009270	0.0390000	0.021300	1	3	BBFV	A	NON
0.0017000	0.14900	0.034000	0.0017800	0.0015300	0.0084900	0.039900	1	4	BBFV	A	NON
0.0017500	0.81800	0.039400	0.0014000	0.0011400	0.0122000	0.033200	1	5	BBFV	A	NON
0.0017100	0.13000	0.023100	0.0011100	0.0008540	0.0085400	0.027300	1	6	BBFV	A	NON
0.0099000	0.25700	0.081700	0.0178000	0.0019800	0.0074200	0.007420	1	1	CTAN	C	TANK
0.0077400	0.44400	0.059400	0.0072300	0.0018100	0.0051600	0.007740	1	2	CTAN	C	TANK
0.0130000	0.41500	0.075700	0.0284000	0.0023500	0.0078300	0.033900	1	3	CTAN	C	TANK
0.0048300	0.02170	0.026600	0.0114000	0.0004830	0.0024200	0.007250	1	4	CTAN	C	TANK
0.0073800	0.63200	0.059000	0.0148000	0.0012300	0.0049200	0.007380	1	5	CTAN	C	TANK
0.0124000	0.13700	0.072200	0.0368000	0.0024900	0.0074700	0.012400	1	7	CTAN	C	TANK
0.0049000	0.09810	0.022100	0.0046600	0.0004900	0.0024500	0.007360	1	6	CTAN	C	TANK
0.0085300	0.26700	0.071100	0.0037000	0.0025600	0.0085300	0.008530	1	1	CTAN	C	TANK
0.0084300	0.07300	0.047700	0.0022500	0.0016900	0.0056200	0.011200	1	2	CTAN	C	TANK
0.0084800	0.47700	0.073500	0.0031100	0.0022600	0.0084800	0.008480	1	3	CTAN	C	TANK
0.0102000	1.00000	0.068900	0.0048500	0.0020400	0.0051000	0.007650	1	4	CTAN	C	TANK

TABLE 33 (continued)

17:28 WEDNESDAY, JANUARY 18, 1989 3

LABNO	FLDCODE	SCALE	FORT	VEHTYP	DAY	VEHNO	FIXBZ	AREAPRSN	ANALYTE	TSHELL	TOTMASS	AL	CA	CR
9514	FCT14BDMET	F	C	T	1	4	B	D	MET	163	75.600	0.203000	0.24400	0.0111000
9541	FCT14BGMET	F	C	T	1	4	B	G	MET	163	75.600	0.242000	0.99600	0.0074900
9515	FCT14BLMET	F	C	T	1	4	B	L	MET	163	75.600	0.365000	0.70300	0.0282000
9517	FCT21ACMET	F	C	T	2	1	A	C	MET	162	69.900	0.214000	0.33400	0.0083500
9518	FCT21ADMET	F	C	T	2	1	A	D	MET	162	69.900	0.273000	0.65000	0.0086300
9520	FCT21ALMET	F	C	T	2	1	A	L	MET	162	69.900	0.099900	1.36000	0.0085600
9521	FCT21BCMET	F	C	T	2	1	B	C	MET	162	69.900	0.041500	0.18300	0.0138000
9522	FCT21BDMET	F	C	T	2	1	B	D	MET	162	69.900	0.139000	0.67200	0.0222000
9542	FCT21BGMET	F	C	T	2	1	B	G	MET	162	69.900	0.025500	0.90800	0.0311000
9523	FCT21BLMET	F	C	T	2	1	B	L	MET	162	69.900	0.120000	0.44400	0.0234000
9524	FCT22ACMET	F	C	T	2	2	A	C	MET	166	92.700	0.240000	0.27700	0.0133000
9525	FCT22ADMET	F	C	T	2	2	A	D	MET	166	92.700	0.199000	0.86700	0.0135000
9527	FCT22ALMET	F	C	T	2	2	A	L	MET	166	92.700	0.139000	0.78700	0.0293000
9528	FCT22BCMET	F	C	T	2	2	B	C	MET	166	92.700	0.368000	1.59000	0.0305000
9529	FCT22BDMET	F	C	T	2	2	B	D	MET	166	92.700	0.143000	0.41700	0.0242000
9543	FCT22BGMET	F	C	T	2	2	B	G	MET	166	92.700	0.131000	0.40500	0.0138000
9530	FCT22BLMET	F	C	T	2	2	B	L	MET	166	92.700	0.095500	0.36800	0.0191000
9533	FCT25ACMET	F	C	T	2	5	A	C	MET	160	58.500	0.165000	0.54000	0.0221000
9534	FCT25ADMET	F	C	T	2	5	A	D	MET	160	58.500	0.169000	0.43900	0.0196000

CU	FE	MG	SB	SR	TI	ZN	SELECT	TREAT	TYPFORT	VLOC	GROUP
0.0083300	0.169000	0.066600	0.0052800	0.00167000	0.0083300	0.0305000	1	5	CTAN	C	TANK
0.0099900	0.099900	0.077400	0.0032500	0.00250000	0.0099900	0.0374000	1	7	CTAN	C	TANK
0.0118000	0.346000	0.104000	0.0040000	0.00235000	0.0141000	0.0353000	1	6	CTAN	C	TANK
0.0111000	0.066800	0.069600	0.0323000	0.00167000	0.0083500	0.0251000	1	1	CTAN	C	TANK
0.0115000	0.170000	0.071900	0.0313000	0.00230000	0.0057500	0.0259000	1	2	CTAN	C	TANK
0.0085600	0.457000	0.054200	0.0088500	0.00228000	0.0028500	0.0257000	1	3	CTAN	C	TANK
0.0055300	0.008300	0.030400	0.0036000	0.00138000	0.0027700	0.0083000	1	4	CTAN	C	TANK
0.0111000	0.016700	0.077800	0.0131000	0.00167000	0.0055600	0.0083400	1	5	CTAN	C	TANK
0.0084900	0.056600	0.031100	0.0005660	0.00170000	0.0028300	0.0141000	1	7	CTAN	C	TANK
0.0117000	0.008770	0.052600	0.0231000	0.00175000	0.0058500	0.0087700	1	6	CTAN	C	TANK
0.0107000	0.072000	0.064000	0.0187000	0.00160000	0.0080000	0.0080000	1	1	CTAN	C	TANK
0.0080800	0.118000	0.061900	0.0083500	0.00215000	0.0053900	0.0296000	1	2	CTAN	C	TANK
0.0080000	0.024000	0.056000	0.0053300	0.00213000	0.0053300	0.0373000	1	3	CTAN	C	TANK
0.0050800	0.010200	0.048300	0.0040600	0.00457000	0.0102000	0.0584000	1	4	CTAN	C	TANK
0.0048500	0.024200	0.036300	0.0014500	0.00145000	0.0048500	0.0096900	1	5	CTAN	C	TANK
0.0092000	0.297000	0.034500	0.0340000	0.00138000	0.0069000	0.0207000	1	7	CTAN	C	TANK
0.0109000	0.106000	0.046400	0.0092800	0.00164000	0.0054600	0.0164000	1	6	CTAN	C	TANK
0.0060400	0.296000	0.058400	0.0016100	0.00201000	0.0060400	0.0282000	1	1	CTAN	C	TANK
0.0035600	0.080100	0.046300	0.0005340	0.00142000	0.0071200	0.0107000	1	2	CTAN	C	TANK

TABLE 33 (continued)

LABNO	FLDCODE	SCALE	FORT	VEHTYP	DAY	VEHNO	FIXBZ	AREAPRSN	ANALYTE	TSHELL	TOTMASS	AL	CA	CR
9536	FCT25ALMET	F	C	T	2	5	A	L	MET	160	58.500	0.213000	1.71000	0.00791000
9602	FKA13ACMET	F	K	A	1	3	A	C	MET	272	126.150	0.016800	0.01020	0.00264000
9603	FKA13ADMET	F	K	A	1	3	A	D	MET	272	126.150	0.000959	0.00096	0.00160000
9605	FKA13ALMET	F	K	A	1	3	A	L	MET	272	126.150	0.000949	0.02180	0.00411000
9606	FKA13BCMET	F	K	A	1	3	B	C	MET	272	126.150	0.008680	0.02770	0.00300000
9607	FKA13BDMET	F	K	A	1	3	B	D	MET	272	126.150	0.001030	0.02270	0.00275000
9608	FKA13BGMET	F	K	A	1	3	B	G	MET	272	126.150	0.006720	0.01840	0.00212000
9609	FKA13BLMET	F	K	A	1	3	B	L	MET	272	126.150	0.011700	0.00755	0.00240000
9610	FKA14ACMET	F	K	A	1	4	A	C	MET	18	102.900	0.001590	0.01800	0.00318000
9611	FKA14ADMET	F	K	A	1	4	A	D	MET	118	102.900	0.001590	0.00955	0.00424000
9613	FKA14ALMET	F	K	A	1	4	A	L	MET	118	102.900	0.063700	0.05470	0.00531000
9614	FKA14BCMET	F	K	A	1	4	B	C	MET	118	102.900	0.001590	0.00902	0.00424000
9615	FKA14BDMET	F	K	A	1	4	B	D	MET	118	102.900	0.010100	0.05470	0.00318000
9616	FKA14BGMET	F	K	A	1	4	B	G	MET	118	102.900	0.001590	0.04670	0.00424000
9617	FKA14BLMET	F	K	A	1	4	B	L	MET	118	102.900	0.012200	0.05310	0.00637000
9619	FKA21ACMET	F	K	A	2	1	A	C	MET	178	160.050	0.007260	0.01940	0.00234000
9620	FKA21ADMET	F	K	A	2	1	A	D	MET	178	160.050	0.000733	0.00073	0.00147000
9622	FKA21ALMET	F	K	A	2	1	A	L	MET	178	160.050	0.006660	0.02370	0.00222000
9623	FKA21BCMET	F	K	A	2	1	B	C	MET	178	160.050	0.013000	0.01870	0.00201000

CU	FE	MG	SB	SR	TI	ZN	SELECT	TREAT	VTYPFORT	VLOC	GROUP
0.007910	0.150000	0.0923000	0.00079100	0.00264000	0.00791000	0.0527000	1	3	CTAN	C	TANK
0.003630	0.007260	0.0019800	0.00009900	0.00013200	0.00099000	0.0029700	1	1	KM1	E	TANK
0.015700	0.000959	0.0009590	0.00604000	0.00070300	0.00224000	0.0086300	1	2	KM1	E	TANK
0.015500	0.013000	0.0025300	0.00161000	0.00066400	0.00253000	0.0108000	1	3	KM1	E	TANK
0.015400	0.005340	0.0040100	0.00120000	0.00073400	0.00100000	0.0100000	1	4	KM1	E	TANK
0.017900	0.011300	0.0034300	0.00261000	0.00085800	0.00309000	0.0113000	1	5	KM1	E	TANK
0.020100	0.002830	0.0021200	0.00240000	0.00088400	0.00353000	0.0134000	1	7	KM1	E	TANK
0.007550	0.002060	0.0020600	0.00068700	0.00024000	0.00137000	0.0037800	1	6	KM1	E	TANK
0.018000	0.001590	0.0042400	0.00143000	0.00021200	0.00478000	0.0122000	1	1	KM1	E	TANK
0.010600	0.001590	0.0021200	0.00143000	0.00021200	0.00265000	0.0074300	1	2	KM1	E	TANK
0.027100	0.010600	0.0058400	0.00180000	0.00117000	0.00690000	0.0223000	1	3	KM1	E	TANK
0.013800	0.001590	0.0037100	0.00138000	0.00021200	0.00318000	0.0069000	1	4	KM1	E	TANK
0.018600	0.005310	0.0106000	0.00170000	0.00117000	0.00371000	0.0111000	1	5	KM1	E	TANK
0.019100	0.001590	0.0063700	0.00207000	0.00133000	0.00478000	0.0382000	1	7	KM1	E	TANK
0.024900	0.005840	0.0084900	0.00154000	0.00133000	0.00531000	0.0191000	1	6	KM1	E	TANK
0.003980	0.000703	0.0032800	0.00016400	0.00016400	0.00187000	0.0426000	1	1	KM1	E	TANK
0.000733	0.009530	0.0007330	0.00014700	0.00009780	0.00097800	0.0169000	1	2	KM1	E	TANK
0.001550	0.005320	0.0051000	0.00017700	0.00008870	0.00200000	0.0552000	1	3	KM1	E	TANK
0.004620	0.006830	0.0040100	0.00030100	0.00014100	0.00281000	0.0365000	1	4	KM1	E	TANK

TABLE 33 (continued)

LABNO	FLDCODE	SC'LE	FRT	VEITYP	DAY	VEHNO	FIXBZ	AREAPRSN	ANALYTE	TSHELL	TOTMASS	AL	CA	CR
9624	FKA21BDMET	F	K	A	2	1	B	D	MET	178	160.050	0.0009920	0.018300	0.00198000
9625	FKA21BGMET	F	K	A	2	1	B	G	MET	178	160.050	0.0260000	0.030700	0.00248000
9626	FKA21BLMET	F	K	A	2	1	B	L	MET	178	160.050	0.0109000	0.023100	0.00198000
9627	FKA22ACMET	F	K	A	2	2	A	C	MET	124	137.100	0.0022600	0.044700	0.00301000
9628	FKA22ADMET	F	K	A	2	2	A	D	MET	124	137.100	0.0019700	0.024600	0.00262000
9630	FKA22ALMET	F	K	A	2	2	A	L	MET	124	137.100	0.0143000	0.034800	0.00317000
9631	FKA22BCMET	F	K	A	2	2	B	C	MET	124	137.100	0.0025100	0.031600	0.00282000
9632	FKA22BDMET	F	K	A	2	2	B	D	MET	124	137.100	0.0011700	0.041600	0.00233000
9633	FKA22BGMET	F	K	A	2	2	B	G	MET	124	137.100	0.0013000	0.042500	0.00347000
9634	FKA22BLMET	F	K	A	2	2	B	L	MET	124	137.100	0.0359000	0.061400	0.00315000
9637	FKA25ACMET	F	K	A	2	5	A	C	MET	77	154.700	0.0009630	0.000963	0.00257000
9640	FKA25ALMET	F	K	A	2	5	A	L	MET	77	154.700	0.0007480	0.018400	0.00150000
9702	FKT13ACMET	F	K	T	1	3	A	C	MET	331	177.600	0.0006230	0.021000	0.00187000
9703	FKT13ADMET	F	K	T	1	3	A	D	MET	331	177.600	0.0006270	0.017300	0.00125000
9705	FKT13ALMET	F	K	T	1	3	A	L	MET	331	177.600	0.0210000	0.025300	0.00227000
9706	FKT13BCMET	F	K	T	1	3	B	C	MET	331	177.600	0.0044700	0.023000	0.00313000
9707	FKT13BDMET	F	K	T	1	3	B	D	MET	331	177.600	0.0006270	0.021100	0.00188000
9708	FKT13BGMET	F	K	T	1	3	B	G	MET	331	177.600	0.0012500	0.067700	0.00293000
9709	FKT13BLMET	F	K	T	1	3	B	L	MET	331	177.600	0.0259000	0.036400	0.00334000

CU	FE	MG	SB	SR	TI	ZN	SELECT	TREAT	VTYPFORT	VLOC	GROUP
0.001740	0.002980	0.0029800	0.00032200	0.00009920	0.00124000	0.0379000	1	5	KM1	E	TANK
0.004220	0.010900	0.0079400	0.00029800	0.00017400	0.00223000	0.0657000	1	7	KM1	E	TANK
0.000992	0.007440	0.0047100	0.00007440	0.00017400	0.00099200	0.0290000	1	6	KM1	E	TANK
0.006770	0.006770	0.0086400	0.00030100	0.00078900	0.00263000	0.0432000	1	1	KM1	E	TANK
0.005240	0.008520	0.0039300	0.00019700	0.00036100	0.00164000	0.0203000	1	2	KM1	E	TANK
0.006020	0.013000	0.0047500	0.00019000	0.00066500	0.00222000	0.0323000	1	3	KM1	E	TANK
0.005010	0.005950	0.0050100	0.00018800	0.00065800	0.00157000	0.0395000	1	4	KM1	E	TANK
0.005050	0.028800	0.0058300	0.00121000	0.00015600	0.00194000	0.0194000	1	5	KM1	E	TANK
0.004770	0.001300	0.0069400	0.00013000	0.00017300	0.00217000	0.0243000	1	7	KM1	E	TANK
0.006610	0.012600	0.0110000	0.00028300	0.00069300	0.00252000	0.0507000	1	6	KM1	E	TANK
0.000642	0.000963	0.0009630	0.00009630	0.00022500	0.00032100	0.0016100	1	1	KM1	E	TANK
0.000748	0.002490	0.0029900	0.00007480	0.00009970	0.00074800	0.0182000	1	3	KM1	E	TANK
0.047800	0.002490	0.0049900	0.00540000	0.00222000	0.00208000	0.0139000	1	1	KTAN	F	TANK
0.020900	0.007310	0.0018800	0.00188000	0.00117000	0.00083600	0.0054300	1	2	KTAN	F	TANK
0.060100	0.008440	0.0057700	0.00758000	0.00270000	0.00227000	0.0196000	1	3	KTAN	F	TANK
0.006480	0.009160	0.0033500	0.00067000	0.00008940	0.00089400	0.0042500	1	4	KTAN	F	TANK
0.017600	0.008570	0.0029300	0.00249000	0.00113000	0.00083600	0.0073100	1	5	KTAN	F	TANK
0.006690	0.002510	0.0163000	0.00075200	0.00046000	0.00167000	0.0012500	1	7	KTAN	F	TANK
0.051000	0.065800	0.0077300	0.00372000	0.00259000	0.00188000	0.0157000	1	6	KTAN	F	TANK

TABLE 33 (continued)

LABNO	FLDCODE	SCALE	FORT	VEHTYP	DAY	VEHNO	FIXBZ	AREAPRSN	ANALYTE	TSHELL	TOTMASS	AL	CA	CR
9710	FKT14ACMET	F	K	T	1	4	A	C	MET	577	155.550	0.006660	0.015500	0.0016700
9711	FKT14ADMET	F	K	T	1	4	A	D	MET	577	155.550	0.000469	0.013000	0.0009380
9713	FKT14ALMET	F	K	T	1	4	A	L	MET	577	155.550	0.000476	0.014100	0.0009520
9714	FKT14BCMET	F	K	T	1	4	B	C	MET	577	155.550	0.000504	0.014000	0.0008400
9715	FKT14BDMET	F	K	T	1	4	B	D	MET	577	155.550	0.000476	0.013500	0.0023800
9716	FKT14BGMET	F	K	T	1	4	B	G	MET	577	155.550	0.003440	0.017700	0.0014100
9717	FKT14BLMET	F	K	T	1	4	B	L	MET	577	155.550	0.003380	0.014000	0.0016900
9202	FSM13ACMET	F	S	M	1	3	A	C	MET	12	144.000	0.006420	0.034100	0.0010100
9203	FSM13ADMET	F	S	M	1	3	A	D	MET	12	144.000	0.001680	0.034300	0.0010100
9205	FSM13ALMET	F	S	M	1	3	A	L	MET	12	144.000	0.001010	0.022200	0.0030200
9206	FSM13BCMET	F	S	M	1	3	B	C	MET	12	144.000	0.011800	0.030400	0.0010100
9207	FSM13BDMET	F	S	M	1	3	B	D	MET	12	144.000	0.001010	0.032200	0.0010100
9208	FSM13BLMET	F	S	M	1	3	B	L	MET	12	144.000	0.011300	0.030700	0.0034100
9209	FSM14ACMET	F	S	M	1	4	A	C	MET	16	192.000	0.018000	0.261000	0.0022400
9210	FSM14ADMET	F	S	M	1	4	A	D	MET	16	192.000	0.011300	0.147000	0.0021200
9212	FSM14ALMET	F	S	M	1	4	A	L	MET	16	192.000	0.006360	0.040300	0.0021200
9213	FSM14BCMET	F	S	M	1	4	B	C	MET	16	192.000	0.042400	0.070600	0.0021200
9214	FSM14BDMET	F	S	M	1	4	B	D	MET	16	192.000	0.010600	0.070600	0.0028200
9215	FSM14BLMET	F	S	M	1	4	B	L	MET	16	192.000	0.054400	0.153000	0.0070600

CU	FE	MG	SB	SR	TI	ZN	SELECT	TREAT	VTYPFORT	VLOC	GROUP
0.026200	0.001330	0.0021700	0.00416000	0.00123000	0.00233000	0.0125000	1	1	KTAN	F	TANK
0.009540	0.000469	0.0010900	0.00227000	0.00061000	0.00078200	0.0031300	1	2	KTAN	F	TANK
0.026200	0.000952	0.0020600	0.00653000	0.00140000	0.00238000	0.0162000	1	3	KTAN	F	TANK
0.019200	0.000504	0.0020200	0.00282000	0.00103000	0.00202000	0.0094100	1	4	KTAN	F	TANK
0.019000	0.006500	0.0017400	0.00452000	0.00095200	0.00159000	0.0090400	1	5	KTAN	F	TANK
0.028300	0.003600	0.0029700	0.00532000	0.00139000	0.00250000	0.0139000	1	7	KTAN	F	TANK
0.015400	0.002540	0.0016900	0.00338000	0.00089600	0.00186000	0.0117000	1	6	KTAN	F	TANK
0.019300	0.013900	0.0016900	0.00006760	0.00006760	0.00033800	0.0043900	1	1	SM10	B	NON
0.022200	0.010400	0.0010100	0.00006720	0.00006720	0.00033600	0.0060500	1	2	SM10	B	NON
0.020800	0.018100	0.0010100	0.00006720	0.00006720	0.00033600	0.0040300	1	3	SM10	B	NON
0.022600	0.019300	0.0037200	0.00013500	0.00006760	0.00067600	0.0037200	1	4	SM10	B	NON
0.000672	0.002020	0.0010100	0.00006720	0.00006720	0.00033600	0.0010100	1	5	SM10	B	NON
0.021500	0.025900	0.0020500	0.00020500	0.00006820	0.00034100	0.0034100	1	6	SM10	B	NON
0.046400	0.059900	0.0067300	0.00029900	0.00015000	0.00150000	0.0120000	1	1	SM10	B	NON
0.109000	0.043800	0.0021200	0.00014100	0.00014100	0.00212000	0.0219000	1	2	SM10	B	NON
0.029700	0.051600	0.0021200	0.00014100	0.00014100	0.00070600	0.0070600	1	3	SM10	B	NON
0.063600	0.093200	0.0106000	0.00042400	0.00014100	0.00212000	0.0134000	1	4	SM10	B	NON
0.033900	0.031100	0.0021200	0.00028200	0.00014100	0.00070600	0.0134000	1	5	SM10	B	NON
0.066400	0.088300	0.0169000	0.00162000	0.00035300	0.00212000	0.0162000	1	6	SM10	B	NON

TABLE 33 (continued)

LABNO	FLDCODE	SCALE	FORT	VEHTYP	DAY	VEHNO	FIXBZN	AREAPRSN	ANALYTE	TSHELL	TOTMASS	AL	CA	CR
9217	FSM21ACMET	F	S	M	2	1	A	C	MET	10	120	0.002540	0.008480	0.0076300
9218	FSM21ADMET	F	S	M	2	1	A	D	MET	10	120	0.010800	0.005830	0.0025000
9220	FSM21ALMET	F	S	M	2	1	A	L	MET	10	120	0.010600	0.021100	0.0024400
9221	FSM21BCMET	F	S	M	2	1	B	C	MET	10	120	0.006810	0.027200	0.0034000
9222	FSM21BDMET	F	S	M	2	1	B	D	MET	10	120	0.002540	0.002540	0.0042300
9224	FSM22ACMET	F	S	M	2	2	A	C	MET	8	96	0.014900	0.040900	0.0027900
9225	FSM22ADMET	F	S	M	2	2	A	D	MET	8	96	0.018700	0.033800	0.0026700
9228	FSM22BCMET	F	S	M	2	2	B	C	MET	8	96	0.071200	0.117000	0.0026700
9229	FSM22BDMET	F	S	M	2	2	B	D	MET	8	96	0.002670	0.002670	0.0026700
9230	FSM22BLMET	F	S	M	2	2	B	L	MET	8	96	0.023100	0.063200	0.0026700
9102	PSM13ACMET	P	S	M	3	3	A	C	MET	16	192	0.003370	0.001120	0.0037400
9103	PSM13ADMET	P	S	M	3	3	A	D	MET	16	192	0.001030	0.001030	0.0027600
9104	PSM13ALMET	P	S	M	3	3	A	L	MET	16	192	0.001100	0.019400	0.0043800
9106	PSM13BCMET	P	S	M	3	3	B	C	MET	16	192	0.001140	0.016300	0.0026600
9107	PSM13BDMET	P	S	M	3	3	B	D	MET	16	192	0.005520	0.001840	0.0042900
9108	PSM1'BLMET	P	S	M	3	3	B	L	MET	16	192	0.001140	0.032300	0.0030400
9109	PSM14ACMET	P	S	M	3	4	A	C	MET	16	192	0.001220	0.173000	0.0032600
9110	PSM14ADMET	P	S	M	3	4	A	D	MET	16	192	0.001040	0.001040	0.0170000
9111	PSM14ALMET	P	S	M	3	4	A	L	MET	16	192	0.001080	0.076400	0.0028800

CU	FE	MG	SB	SR	TI	ZN	SELECT	TREAT	TYPFORT	VLOC	GROUP
0.0263000	0.461000	0.0025400	0.00017000	0.00017000	0.00084800	0.0033900	1	1	SM10	B	NON
0.0283000	0.052500	0.0025000	0.00175000	0.00016700	0.00083400	0.0041700	1	2	SM10	B	NON
0.0227000	0.036600	0.0065000	0.00016200	0.00016200	0.00081200	0.0024400	1	3	SM10	B	NON
0.0357000	0.020400	0.0025500	0.00111000	0.00017000	0.00085100	0.0059600	1	4	SM10	B	NON
0.0067700	0.044800	0.0025400	0.00016900	0.00016900	0.00084600	0.0025400	1	5	SM10	B	NON
0.0177000	0.012100	0.0046500	0.00251000	0.00018600	0.00092900	0.0046500	1	1	SM10	B	NON
0.0125000	0.013400	0.0026700	0.00017800	0.00017800	0.00089000	0.0026700	1	2	SM10	B	NON
0.0187000	0.053400	0.0142000	0.00134000	0.00017800	0.00178000	0.0026700	1	4	SM10	B	NON
0.0080100	0.008010	0.0026700	0.00017800	0.00017800	0.00089000	0.0026700	1	5	SM10	B	NON
0.0142000	0.021400	0.0026700	0.00035600	0.00017800	0.00089000	0.0035600	1	6	SM10	B	NON
0.0097300	0.005240	0.0011200	0.00015000	0.00112000	0.00112000	0.0052400	1	1	SM10	B	NON
0.0079200	0.001030	0.0010300	0.00013800	0.00103000	0.00103000	0.0044800	1	2	SM10	B	NON
0.0011000	0.001100	0.0021900	0.00014600	0.00110000	0.00110000	0.0011000	1	3	SM10	B	NON
0.0022800	0.001140	0.0011400	0.00003800	0.00114000	0.00114000	0.0034200	1	4	SM10	B	NON
0.0067400	0.001840	0.0018400	0.00012300	0.00184000	0.00184000	0.0018400	1	5	SM10	B	NON
0.0095000	0.001140	0.0118000	0.00026600	0.00114000	0.00114000	0.0022800	1	6	SM10	B	NON
0.0571000	0.001220	0.0216000	0.00008150	0.00122000	0.00122000	0.0106000	1	1	SM10	B	NON
0.0010400	0.044800	0.0010400	0.00003480	0.00104000	0.00104000	0.0010400	1	2	SM10	B	NON
0.0010800	0.006480	0.0021600	0.00036000	0.00108000	0.00108000	0.0068500	1	3	SM10	B	NON

TABLE 33 (continued)

LABNO	FLDCODE	SCALE	FORT	VEHTYP	DAY	VEHNO	FIXBZ	AREAPRSN	ANALYTE	TSHELL	TOTMASS	AL	CA	CR
9113	PSM14BCMET	P	S	M	3	4	B	C	MET	16	192	0.001070	0.0264000	0.00250000
9114	PSM14BDMET	P	S	M	3	4	B	D	MET	16	192	0.001760	0.0010600	0.00352000
9115	PSM14BLMET	P	S	M	3	4	B	L	MET	16	192	0.443000	0.0330000	0.00311000
9116	PSM21ACMET	P	S	M	4	1	A	C	MET	16	192	0.005040	0.0009450	0.00220000
9117	PSM21ADMET	P	S	M	4	1	A	D	MET	16	192	0.001210	0.0224000	0.00303000
9118	PSM21ALMET	P	S	M	4	1	A	L	MET	16	192	0.001080	0.0010800	0.00253000
9120	PSM21BCMET	P	S	M	4	1	B	C	MET	16	192	0.000952	0.0009520	0.00476000
9121	PSM21BDMET	P	S	M	4	1	B	D	MET	16	192	0.024400	0.0388000	0.00431000
9122	PSM21BLMET	P	S	M	4	1	B	L	MET	16	192	0.031000	0.0011600	0.00155000
9123	PSM22ACMET	P	S	M	4	2	A	C	MET	18	216	0.001730	0.0010400	0.00277000
9124	PSM22ADMET	P	S	M	4	2	A	D	MET	18	216	0.002900	0.0009670	0.00129000
9125	PSM22ALMET	P	S	M	4	2	A	L	MET	18	216	0.004650	0.0143000	0.00145000
9127	PSM22BCMET	P	S	M	4	2	B	C	MET	18	216	0.001640	0.0009850	0.00361000
9128	PSM22BDMET	P	S	M	4	2	B	D	MET	18	216	0.002980	0.0343000	0.00261000
9129	PSM22BLMET	P	S	M	4	2	B	L	MET	18	216	0.001750	0.0017500	0.00409000

CU	FE	MG	SB	SR	TI	ZN	SELECT	TREAT	VTYPFORT	VLOC	GROUP
0.0042800	0.0010700	0.0039200	0.000035700	0.00107000	0.00107000	0.0017800	1	4	SM10	B	NON
0.0141000	0.0010600	0.0010600	0.000070400	0.00106000	0.00106000	0.0042200	1	5	SM10	B	NON
0.0093200	0.0011600	0.0113000	0.000194000	0.00116000	0.00116000	0.0120000	1	6	SM10	B	NON
0.0018900	0.0009450	0.0009450	0.000126000	0.00094500	0.00094500	0.0015700	1	1	SM10	B	NON
0.0024200	0.0009080	0.0069600	0.000060600	0.00090800	0.00090800	0.0048400	1	2	SM10	B	NON
0.0010800	0.0010800	0.0010800	0.000253000	0.00108000	0.00108000	0.0010800	1	3	SM10	B	NON
0.0009520	0.0009520	0.0009520	0.000031700	0.00095200	0.00095200	0.0009520	1	4	SM10	B	NON
0.0028700	0.0254000	0.0120000	0.000287000	0.00144000	0.00431000	0.0014400	1	5	SM10	B	NON
0.0019400	0.0759000	0.0139000	0.000387000	0.00116000	0.00155000	0.0011600	1	6	SM10	B	NON
0.0055500	0.0010400	0.0010400	0.000243000	0.00104000	0.00104000	0.0010400	1	1	SM10	B	NON
0.0161000	0.0009670	0.0009670	0.000129000	0.00096700	0.00096700	0.0045100	1	2	SM10	B	NON
0.0055300	0.0017500	0.0043600	0.000058200	0.00087300	0.00116000	0.0026200	1	3	SM10	B	NON
0.0026300	0.0009850	0.0019700	0.000164000	0.00098500	0.00098500	0.0019700	1	4	SM10	B	NON
0.0037200	0.0011200	0.0067000	0.000372000	0.00112000	0.00112000	0.0033500	1	5	SM10	B	NON
0.0017500	0.0017500	0.0017500	0.000351000	0.00175000	0.00175000	0.0017500	1	6	SM10	B	NON

TABLE 33 (continued)

LEGEND

LABNO:	Laboratory sample number
FLDCODE:	Field code
SCALE:	Full (F) study; preliminary (P) study
FORT:	Benning (B); Carson (C); Knox (K); Sill (S)
VEHTYP:	M3 (B); M109 (M); M1 (A); M60 (T)
VEHNO:	Vehicle number
FIXBZ:	General area (A); breathing zone (B)
AREAPRSN:	Commander (C); driver (D); loader (L); gunner (G)
TSHELL:	Total number of shells
TOTMASS:	Total mass of propellant (kg)
TREAT:	Treatment
GROUP:	Tank or non-tank

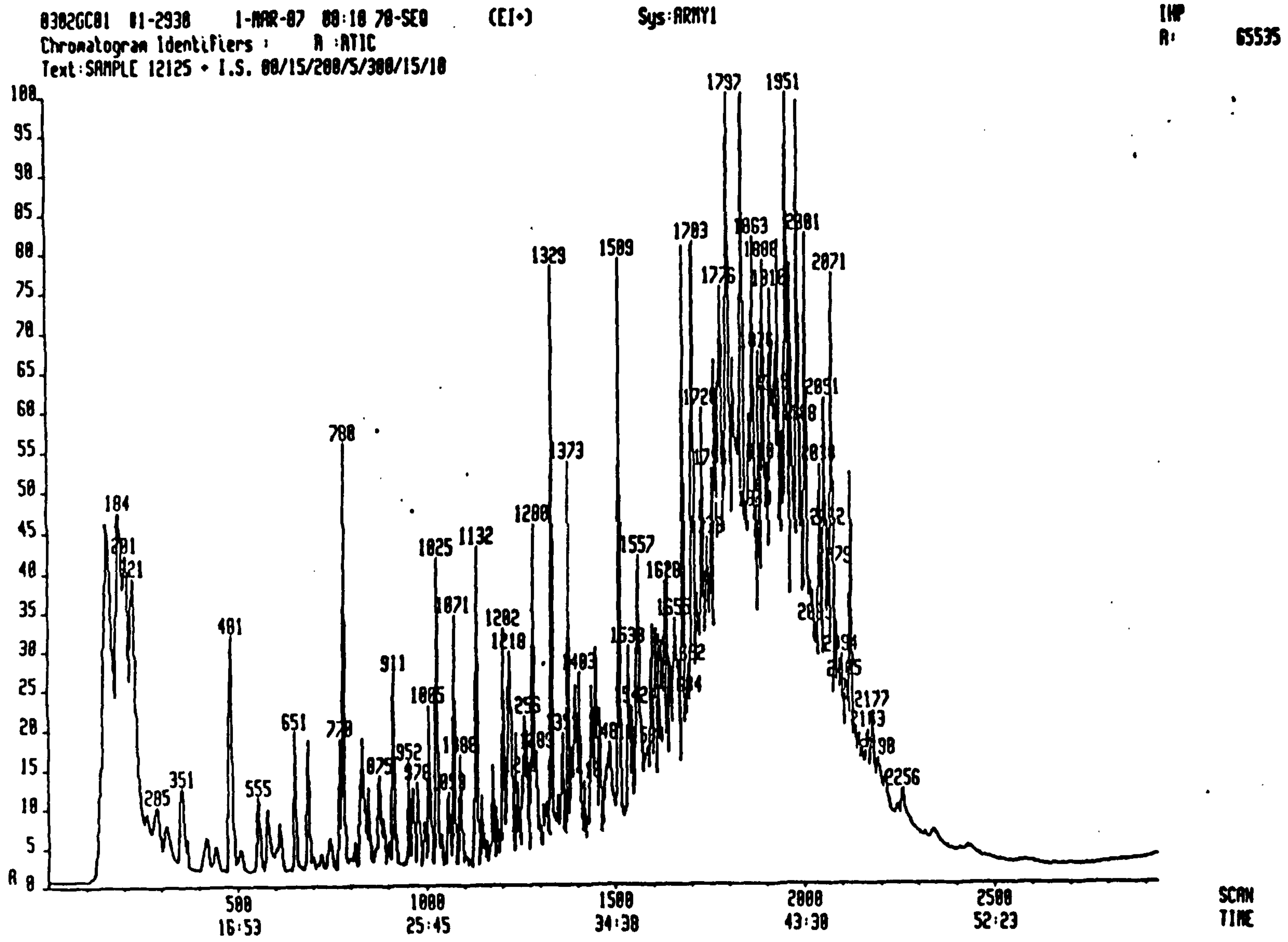


Figure 32. Typical chromatogram from GC/MS.

TABLE 34. ORGANIC COMPOUNDS

Target Compound	Sample Scan	Primary Ion
Dichloromethane-d2	171	88
Carbon dioxide	112	45
Sulphur dioxide	--	64
Acetone	151	58
Dichloromethane	172	84
Dimethyl butane	216	71
Methyl pentane	233	57
Methyl pentane	263	86
Methyl pentene	306	84
Trichloro-ethane	327	117
Benzene	--	78
Cyclohexane	--	84
Dimethyl pentane	444	100
Dimethyl cyclopentane	490	98
Heptane	548	100
Methyl cyclohexane	580	98
Trimethyl cyclopentane	--	112
Ethyl cyclopentane	--	98
Trimethyl cyclopentane	--	112
Trimethyl cyclopentane	--	112
Toluene-d8	671	100
Toluene	682	91
Dimethyl hexane	--	70
Dimethyl cyclohexane	737	112
Ethyl methyl cyclopentane	--	83
Ethyl methyl cyclopentane	--	112
Dimethyl cyclohexane	--	112
Dimethyl cyclohexane	--	112
Octane	821	114
Dimethyl cyclohexane	--	112
Chlorobenzene-d5	858	117
Ethyl cyclohexane	868	112
Trimethyl cyclohexane	882	111
Ethyl benzene	913	106
Trimethyl cyclohexane	--	126
Dimethyl benzene	935	106
C9H18 hydrocarbon	--	126
Dimethyl benzene	979	106
Ethyl methyl cyclohexane	1000	126
Nonane	1043	128
Methyl ethyl cyclohexane	--	126

TABLE 34 (continued)

Target Compound	Sample Scan	Primary Ion
Propyl cyclohexane	1082	126
Ethyl methyl benzene	1126	120
Dimethyl octane	--	98
Dimethyl octene	1128	140
Trimethyl benzene	1141	120
Trimethyl benzene	1157	120
Benzofuran	--	118
Trimethyl benzene	1186	120
Dichloro benzene	--	146
C10H20 hydrocarbon	1202	140
Diethyl dimethyl cyclohexane	1211	139
Methyl propyl cyclohexane	1221	140
C10H18 hydrocarbon	1226	138
Trimethyl benzene	1233	120
Decane	1238	142
Ethyl dimethyl benzene	1248	134
Ethenyl methyl benzene	1250	117
Limonene	1265	136
Butyl cyclohexane	1279	140
Methyl propyl benzene	1296	134
Butyl benzene	--	134
C11H22 hydrocarbon	1319	154
C11H22 hydrocarbon	1334	154
Dimethyl ethyl benzene	1353	134
Dihydro methyl indene	1345	132
Dihydro methyl indene	1345	132
Ethyl dimethyl benzene	1353	134
Undecene	1381	154
C11H22 hydrocarbon	1385	154
Diethyl benzene	1390	134
Decahydro methyl naphthalene	1406	152
Undecane	1416	156
Decahydro methyl naphthalene	1432	152
Methyl propenyl benzene	1451	132
Pentyl cyclohexane	1459	154
Tetrahydro naphthalene	1465	132
Methyl propyl methyl benzene	1472	148
Naphthalene	1492	128
Dimethyl dihydro indene	1520	146
Dodecane	1587	170
Dimethyl dihydro indene	--	146
Hexyl cyclohexane	1629	168

TABLE 34 (continued)

Target Compound	Sample Scan	Primary Ion
Dimethyl dihydro indene	--	146
Methyl naphthalene	1671	142
Methyl naphthalene	1694	142
Tridecane	1744	184
C14H30 hydrocarbon	1770	127
C14H26 hydrocarbon	1772	194
Heptyl cyclohexane	1786	182
C14H30 hydrocarbon	1816	126
Ethyl naphthalene	--	156
Dimethyl tetrahydro naphthalene	--	160
Dimethyl naphthalene	1836	156
Dimethyl naphthalene	1836	156
C15H32 hydrocarbon	1856	183
Dimethyl naphthalene	1859	156
Ethyl naphthalene	1859	156
Tetradecane	1881	198
Dimethyl naphthalene	1883	156
Hexamethyl octahydro indene	1898	208
Dimethyl naphthalene	1900	156
C16H34 hydrocarbon	1978	183
Trimethyl naphthalene	1981	170
Trimethyl naphthalene	2010	170
Pentadecane	2018	212
Trimethyl naphthalene	2034	170
Propenyl naphthalene	--	168
Hexadecane	2148	226
Heptadecane	2298	240
Octadecane	2436	254

TABLE 35

SELECTED ORGANIC VAPORS ($\mu g/m^3$)

Compound	Acronym	Mean Range	Maximum
Acetone	ACET	15 - 147	540
Dichloromethane	DCM	2.8 - 154	1200
Trichloroethane	TCE	0.9 - 231	1500
Benzene	BNZ	25 - 232	490
Dimethylcyclohexane	DMCH	1.7 - 81.2	530
Dimethylbenzene	DMBZ	7.0 - 292	690
Nonane	NON	0.7 - 499	1900
Benzofuran	BZF	<0.1 - 0.1	1.2
Dichlorobenzene	DCB	<0.1 - 6.3	42
Dimethyldihydroindene	IND	8.7 - 220	720
Methylnaphthalene	MNAP	13 - 110	220
Trimethylnaphthalene	TMN	<0.1 - 9.2	460

3.3 STATISTICAL COMPARISONS

3.3.1 Fundamental Observations

The information presented in the previous section summarizes the concentration levels of potentially toxic pollutants found in selected armored vehicles during weapon firing exercises. In terms of future monitoring and risk assessment, it may also be useful to understand if there are statistically significant differences in mean concentrations of analytes:

- Among the different vehicle types,

- Among the various crew positions: commander, driver, loader, and gunner (sampled only in tanks), and

- Between the two methods of sampling, general area vs. breathing zone.

The most easily interpreted results would be those where differences for each factor described above are consistent when averaged across the other factors. For example, a simple interpretation would result if the position of the commander were (hypothetically) statistically higher than other crew positions in all vehicle types, in both general area and breathing zone samples, and for all analytes.

Analysis of the field data, however, did not yield such straightforward results. The statistical comparisons were complicated by interactions among the major factors. First, it was observed that statistical similarities and differences between crew positions depend on which vehicle type and which analyte are considered, as well as whether the sample is general area or breathing zone. Second, the mean concentrations were observed to be functions not only of the factors cited above (type of vehicle, crew position, and sampling method) but also of other factors, notably the quantity of ammunition fired. Third, as a result of sampling constraints (i.e., limited vehicle availability at specific forts), effects on concentration due to differences in forts and training scenarios could not be statistically separated from effects of different types of vehicles. Such possible effects could include, for example, the manner in which the soldiers move into and out of the vehicle, or the proportion of different sizes/types of ammunition fired, or the distribution of firing over the time of the exercise (firing intensity). Therefore, in this report, the phrase "differences in vehicle types" is understood to mean differences in the four fort/vehicle-type/training scenario combinations.

3.3.1.1 Design Considerations

Comparisons were made on the basis of linear model analyses which were carried out on the statistical software package "SAS" (SAS Institute Inc., Cary, North Carolina) using "PROC GLM" (general linear model). Statistically significant differences are those for which the alpha level is 0.05. Since the greatest number of observations was available for CO concentrations, and since observed values spanned the range between upper and lower reporting limits, results of CO analyses were used as a model for applying consistent logic to analysis of the remaining analytes.

Sampling of an analyte done at the same fort on the same vehicle type but on different days was considered to constitute replication of the experiment. In preliminary CO analyses, a term quantifying the effect of day-to-day variability was initially included in the model. However, the presence of significant interactions involving this term gave support to the view that day-to-day variability should be included as part of the error term.

Due to the availability of only one day (no replication) of sampling of the M60 tank at Fort Knox and the M109 at Fort Carson, these data were combined with those of the M60 tank at Fort Carson and the M109 at Fort Sill, respectively. Thus, differences in vehicle types discussed in this document are understood to mean differences in these particular combinations of four fort/vehicle-type/training scenarios:

(1) Fort Benning, Bradley Fighting Vehicle (M3), training;
(2) Fort Carson & Fort Sill, M109, battle and training;
(3) Fort Carson & Fort Knox, M60 tank, battle and training;
(4) Fort Knox, M1 tank, training.

It should be noted that the statistical model used adjusts for differences in the amount of firing (for a given type of vehicle) and, therefore, in this regard the combining of training and battle scenarios is not unreasonable.

Crew positions and sampling method were viewed as combinations, forming six "treatments" for non-tank vehicles and seven treatments for tank vehicles as follows:

(1) general area/commander samples - treatment 1
(2) general area/driver samples - treatment 2
(3) general area/loader samples - treatment 3
(4) breathing zone/commander samples - treatment 4
(5) breathing zone/driver samples - treatment 5
(6) breathing zone/loader samples - treatment 6
(7) breathing zone/gunner samples - treatment 7 (tanks only)

Differences in general area samples versus breathing zone samples were addressed in two ways. Specifically, the comparisons were made by examining for groupings of statistically similar (or dissimilar) treatment

effects as described above, or through a paired t-test using CO peak and average concentration data.

3.3.1.2 Vehicle Considerations

For each type of vehicle, the concentrations of combustion products are likely influenced by the following three parameters:

(1) The type and amount of ammunition fired (e.g., quantity of combustion product);

(2) The manner in which the exercise is conducted and troops are deployed including considerations such as:

-- use of ventilation fans,
-- opening or closing of vehicle hatches, and
-- movement of soldiers within the vehicle and in and out of the vehicle; and

(3) The physical or engineering characteristics of the vehicle such as:

-- the uniformity and rapidity with which air is circulated and fresh air is exchanged,
-- the amount of combustion products escaping into the vehicle after weapons discharge,
-- location of engine exhaust (another possible source of combustion products), and
-- the volume of air contained in the vehicle.

These parameters combine to define for each vehicle type a relationship between amount of firing and concentration. An example of the way in which these parameters combine to affect concentration can be seen by examining the means of "peak CO" and "average CO" concentrations as shown in Table 36. Note, for example, that despite the larger total amount of propellant consumed, the M109s have only roughly one tenth the average CO concentration of the M1 and M60 tanks.

The first two of the three parameters are variable and in comparing vehicle types this needs to be considered. Comparisons of vehicles are meaningful to the extent that the scenarios tested are representative of typical forts, conditions, and normal use of the vehicles, including type and amount of munitions fired, and deployment of soldiers.

3.3.2 Comparison of Vehicle Types

A type of statistical linear model called "analysis of covariance" was used to analyze the concentrations of analytes seen and differences in concentrations among vehicle types, crew positions and sampling methods. The model can be understood conceptually as a mathematical equation that describes each observed concentration as being equal to the mean of all observations plus (or minus) other terms (parameters)

TABLE 36

CO CONCENTRATIONS (ppm) BY VEHICLE

CO concentration is a function of amount of firing, troop activities, and physical characteristics of the vehicles

Fort/Vehicle Type	No. of Vehicles Sampled	Mean of Covariate, Mass Dur*	Mean Average Concentration	Mean of Covariate, Mass Min**	Mean Peak Concentration
Fort Sill and Fort Carson M109	104	0.553	3.60	1.200	232.2
Fort Benning M3 (Bradley Fighting Vehicle)	58	0.060	4.65	0.237	391.9
Fort Carson and Fort Knox M60 Tank	74	0.432	35.89	1.683	857.7
Fort Knox M1 Tank	39	0.449	30.74	0.602	1460.3

*Mass Dur = Mass of propellant (kg) divided by drill exercise time (min). It is a measure of the amount of firing, or amount of combustion products.

**Mass Min = Mass of propellant (kg) divided by firing time (min). This is also a measure of amount of firing.

that quantify the effects of factors such as type of vehicle, crew position, and sample methods, as deviations from the mean. A term (or terms) is included in the model, called a covariate or concomitant variable, which "adjusts" for the fact that concentrations are a function of the amount of ammunition firing (propellant mass or numbers of shells).

The analysis of covariance was used on four sets of data: average CO concentrations, peak CO concentrations, selected metal (Al, Ca, Cr, Cu, Fe, Mg, Sb, Sr, Ti, Zn) concentrations, and selected organic compound (ACET, DCM, TCE, BNZ, DMCH, DMBZ, NON, BZF, DCB, IND, MNAP, TMN) concentrations.

For each set of data an analysis of covariance model of the form described below was explored:

$$Y_{jk} = u + FX_{jk} + V_j + (FX_{jk} * V_j) + E_{jk}$$

where:

- Y_{jk} = the observed concentration at fort/vehicle-type j on replicate k (a particular vehicle sampled on a particular day)
- u = overall mean concentration
- F = a regression coefficient for the relationship of concentration to firing intensity
- X_{jk} = covariate, a measure of firing intensity for each replicate k
- V_j = fort/vehicle type parameter (j=1,4)
- E_{jk} = error term, or estimate of variability for each Y_{jk}

For purposes of comparing vehicle types, breathing-zone gunner samples (treatment 7), found only in tanks, were dropped from the analysis. Primarily, this model was used to confirm statistically what has been described above, namely, that the different vehicles do not share a common linear relationship between concentration and amount of munitions fired. Also, preliminary analyses indicated that those treatments (combinations of crew position and sampling method) which were significantly different from others depended on the vehicle type. In light of this evidence, treatment comparisons discussed below were made only for data from the same vehicle type.

Where the analysis of covariance model indicated significant differences, vehicle comparisons were made using the SAS Tukey option in PROC GLM which invokes the Kramer modification for unbalanced designs. Comparisons were based, therefore, on raw means (not adjusted for the covariate) under the assumption that data are representative of typical use and conditions. It was noted during analysis that the tank data seemed to have more variability than non-tank data. Comparisons of means were made nevertheless, assuming their practical importance in characterizing vehicles.

3.3.3 Comparison of Treatments (Combinations of Crew Positions and Type of Sample, General Area vs Breathing Zone)

The analysis of covariance defines a linear relationship (regression) between the amount of firing or combustion product (the covariate) and the concentration. Using this relationship the model "adjusts" the comparisons for differences in amount of firing (propellant mass). This adjustment makes it easier to detect differences by reducing variability in the concentration data that is due primarily to different amounts of firing. This is especially helpful, for example, in combining data from individual vehicles, different days, and different forts.

A model was used for detecting treatment differences within each vehicle type of the form:

$$Y_{kl} = u + FX_{kl} + T_k + E_{kl}$$

where:

- Y_{kl} = the observed concentration for treatment k for replicate l (a particular vehicle sampled on a particular day)
- u = overall mean concentration
- F = a regression coefficient for the relationship of concentration to firing intensity (slope of the line)
- X_{kl} = covariate, a measure of firing intensity for each replicate. Note that it is a constant for all k's/treatments within each individual vehicle
- T_k = treatment parameter, that is, each unique combination of crew position and sampling method, such as "area-commander", k=1,7
- E_{kl} = error term, or estimate of variability for each Y_{kl}

For these analyses treatment 7, breathing zone gunner, was included in the tank data.

Significant differences may be indicated by the above model, but determination of which treatment(s) are different (or similar) is done with an additional statistical test such as the Tukey-Kramer method used for vehicle comparisons. However, where concentration means need to be adjusted for amount of firing, the Tukey-Kramer method is inappropriate. Alternatively, adjusted concentration means, called least squares means, were obtained from the model.

Raw (unadjusted) treatment means equal the least squares (adjusted) means when the covariate mean and the number of samples are equal for each treatment. In this case comparisons were made using the Tukey-Kramer test. Where least squares means and raw means differ, comparisons were made using least squares means with an alpha level of 0.010. Results

using the Tukey-Kramer test are also presented for comparison where the raw and adjusted means do not differ greatly.

Where sample sizes are unequal, presentation of statistical differences is awkward due to possible multiple groupings of statistically similar/dissimilar treatments. Such is the case, for example, with the M109 concentration differences presented in Table 44 in Section 3.3.5.2. The differences are described briefly in the tables; the computer output provided in Appendix D should be consulted for a more statistically formal presentation of comparisons using confidence intervals.

3.3.4 Differences among Vehicle Types

3.3.4.1 Carbon Monoxide

For both average and peak CO concentrations, the tanks showed statistically significantly higher means than the non-tanks (alpha = 0.05). Additionally, for peak concentrations, the Fort Knox M1 tank was statistically higher than the M60 tanks from Fort Knox and Fort Carson combined. Results are presented in Table 37 including concentration and covariate means, and statistical groupings of vehicles based on Tukey (Kramer modified) multiple comparisons. Vehicles with the same (different) group letter code are statistically the same (different).

3.3.4.2 Organic Compounds

For nine of the ten organic compounds analyzed, the M60 tank concentrations were statistically higher than all other vehicles (the exception being acetone). No differences between vehicles were detected for dichloromethane. Results are presented in Table 38 including concentration and covariate means. Statistical groupings of similar (different) means from the Tukey-Kramer multiple comparisons were straightforward (except for acetone) and are also summarized in Table 38.

3.3.4.3 Metals

For five of the ten metals, the Fort Benning M3 had the highest concentration. It was statistically higher than some other fort/vehicles for seven metals (Table 39). No fort/vehicle differences were detected for copper. Also, no metal samples from Fort Carson were available for comparison.

3.3.4.4 Other Compounds

The graphical representations of mean concentrations of the additional pollutants monitored during this program (Section 3.2) support the observation that the tanks show higher levels than non-tanks. However, on the basis of simple descriptive statistics (mean and standard deviation), statistically significant differences among vehicle types cannot be identified although they may exist as noted previously.

TABLE 37

CO CONCENTRATIONS (ppm) BY VEHICLE

For both average and peak concentrations, tanks showed statistically higher[1] concentrations than non-tanks

Fort/Vehicle Type	No. of Vehicles Sampled	Mean of Covariate, Mass Dur	Mean Average Concentration	Tukey[2] Group	Mean of Covariate, Mass Min	Mean Peak Concentration	Tukey[2] Group
Fort Sill and Fort Carson M109	104	0.553	3.60	A	1.200	232.2	A
Fort Benning M3 (Bradley Fighting Vehicle)	58	0.060	4.65	A	0.237	391.9	A
Fort Carson and Fort Knox M60 Tank	74	0.432	35.89	B	1.683	857.7	B
Fort Knox M1 Tank	39	0.449	30.74	B	0.602	1460.3	C

[1]Alpha = 0.05
[2]Fort/Vehicles with the same (different) letter are statistically the same (different).

Legend: Means within solid boxes are statistically alike.

TABLE 38

ORGANIC CONCENTRATIONS (ug/m^3) BY VEHICLE

The M60 tank showed statistically higher concentrations for most compounds

Fort/Vehicle Type	No. of Vehicles	Total Mass	DCM	ICE	TMN	IND	DMCH	DMBZ	NON	BNZ	MNAP	ACET**
Fort Carson and Fort Knox M60 Tank	31	87.180	106.198	123.213	61.009	146.310	59.231	202.351	336.508	179.377	80.584	99.215
Fort Benning M3 (Bradley Fighting Vehicle)	28	9.611	36.107	36.645	0.007	4.381	1.742	12.292	0.682	114.071	40.425	50.614
Fort Sill and Fort Carson M109	59	150.508	49.944	15.581	12.949	25.299	3.048	21.871	11.638	38.668	15.664	31.893
Fort Knox M1 Tank	18	131.048	8.022	5.040	11.672	10.389	2.284	20.155	12.52	22.289	12.000	25.139
Fort/Vehicle Type comparisons: Synopsis of Tukey-Kramer multiple comparisons*			No differences	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 2	Note 2	Note 3

*See appendix for computer output.
**Differences in sample size make comparisons complex.

Note 1: M60 different from all others; others all similar.
Note 2: M1 and M109 similar; all others different from each other.
Note 3: M3 not different from any others; M60 different from M1 and M109; M1 and M109 not different.

Legend: Means within solid boxes are statistically alike. Dashed boxes denote means different only from means in other dashed boxes.

TABLE 39

METAL CONCENTRATIONS (ug/m^3) BY VEHICLE

The M3 was statistically higher than some other vehicle(s) for 7 of the 10 metals

Fort/Vehicle Type	No. of Vehicles	Total Mass	Cr	Fe	Sr	Al	Ce	Mg	Sb**	Zn	Ti	Cu
Fort Benning M3 (Bradley Fighting Vehicle)	27	10.39	12.9	218.7	3.0	121.4	126.4	32.5	4.2	52.8	10.0	15.1
Fort Carson* and Fort Knox M60 Tank	39	101.40	12.0	151.8	1.7	134.4	431.0	42.6	8.1	16.8	4.9	14.0
Fort Sill M109	46	170.61	3.3	29.6	0.7	19.2	38.0	4.5	0.3	4.8	1.1	17.8
Fort Knox M1 Tank	26	133.33	2.9	6.8	0.5	8.8	25.1	4.4	1.0	21.9	2.3	9.2
Fort/Vehicle Type comparisons			Note 1	Note 1	Note 2	Note 1	Note 3	Note 1	Note 4	Note 5	Note 6	Note 7

*No metal samples were available from Fort Carson.
**Differences in sample size make comparisons complex.

Note 1: M60 and M3 alike but different from others; M109 and M1 alike but different from others.
Note 2: M1 and M109 alike; all others different from each other.
Note 3: M60 different from all others; others all alike.
Note 4: M60 different from all others; M3 and M109 different from each other.
Note 5: M1 and M60 alike; all others different from each other.
Note 6: M3 different from all others; M1 like M60 and M109, but M60 and M109 different from each other.
Note 7: No differences.

Legend: Means within solid boxes are statistically alike. Dashed boxes denote means different only from means in other dashed boxes.

3.3.5 Differences among Treatments (Crew Positions/Type of Sample)

Crew positions and sampling method were viewed as combinations, forming six "treatments" for non-tanks and seven treatments for tanks as follows:

general area/commander samples	- treatment 1
general area/driver samples	- treatment 2
general area/loader samples	- treatment 3
breathing zone/commander samples	- treatment 4
breathing zone/driver samples	- treatment 5
breathing zone/loader samples	- treatment 6
breathing zone/gunner samples	- treatment 7 (tanks only)

3.3.5.1 Carbon Monoxide

For average CO concentrations, no significant differences between treatments were detected for the Fort Carson/Fort Knox M60 tanks, nor for any of the non-tanks: the Fort Benning M3 (Bradley Fighting Vehicle), and the Fort Carson/Fort Sill M109s. For the Fort Knox M1, the general area/driver had statistically lower concentrations than the general area/commander and the breathing zone/loader using least square means comparisons. Results are presented in Table 40.

For peak CO concentrations no significant differences between treatments were seen in the Fort Carson/Fort Sill M109s. For the Fort Knox M1, the general area/driver concentration was statistically different from all others except that of the breathing zone/driver; also, the breathing zone/driver concentration was statistically lower than those of the general area/commander and the breathing zone/loader (Table 41). For the Fort Benning M3 (Bradley Fighting Vehicle) the general area/commander concentration was significantly higher than that of the breathing zone/driver (Table 42). For the Fort Knox/Fort Carson M60 tanks, breathing zone/loader, gunner, and commander concentrations are significantly higher than the general area/driver concentration (Table 43).

3.3.5.2 Organic Compounds

For the Fort Benning M3 (Bradley Fighting Vehicle) no treatment differences were detected for any of the ten compounds. Also, for the Fort Knox M1 tank no treatment differences were detected. For NON, IND, and TMN in the Fort Carson/Fort Sill M109s the general area/loader concentration was significantly higher than all others except that of the general area/driver, while the general area/driver concentration was different than those of all breathing zone positions for IND and TMN as delineated in Table 44. The M60 Fort Carson/Fort Knox tanks showed differences for DMBZ and MNAP, the breathing zone/driver concentration being higher than those of some others as shown in Table 45.

TABLE 40

M1 TANK AVERAGE CO CONCENTRATIONS (ppm)

Area commander and breathing zone loader concentrations are significantly higher than area driver concentrations*

Treatment	No. of Vehicles	Mass Dur	Mean (unadjusted)	Least Squares Mean (adjusted)
1 Area Commander	4	0.431	50.00	48.59
6 Breathing Zone Loader	8	0.445	49.87	49.61
7 Breathing Zone Gunner	8	0.445	33.75	33.48
4 Breathing Zone Commander	7	0.455	27.14	27.76
3 Area Loader	7	0.439	27.14	26.35
5 Breathing Zone Driver	5	0.479	22.00	24.65
2 Area Driver	8	0.445	13.75	13.48

Treatment comparisons using least squares means (adjusted for amount of firing), alpha = 0.010 per comparison.

Area driver significantly different from area commander and breathing zone loader.

Treatment comparisons using Tukey-Kramer multiple comparison test, alpha = 0.05 for experimentwise error rate.

Area driver significantly different from breathing zone loader.

*Differences in sample size make comparisons complex.

Legend: Means within solid boxes are statistically alike. Dashed boxes denote means different only from means in other dashed boxes.

TABLE 41

M1 PEAK CO CONCENTRATIONS (ppm)

Treatment 2 is significantly different from all but 5, while 5 is different from 1 and 6*

Treatment	No. of Vehicles	Mass Min	Mean (unadjusted)	Least Squares Mean (adjusted)
1 Area Commander	4	0.563	2155	2105
6 Breathing Zone Loader	8	0.599	1981	1978
4 Breathing Zone Commander	7	0.619	1607	1630
3 Area Loader	7	0.589	1637	1621
7 Breathing Zone Gunner	8	0.599	1593	1590
5 Breathing Zone Driver	5	0.635	854	898
2 Area Driver	8	0.599	688	685

Treatment comparisons using least squares means (adjusted for amount of firing), alpha = 0.010 per comparison.

Area driver different from all others except breathing zone driver. Breathing zone driver different from area commander and breathing zone loader.

Treatment comparisons using Tukey-Kramer multiple comparisons test, alpha = 0.05 for experimentwise error rate.

Same as least squares comparisons.

*Differences in sample size (no. of vehicles) make comparisons complex.
Legend: Means within solid boxes are statistically alike. Dashed boxes denote means different only from means in other dashed boxes.

TABLE 42

M3 PEAK CO CONCENTRATIONS (ppm)

Area commander concentrations are significantly higher than breathing zone loader concentrations

Treatment	No. of Vehicles	Mass Min	Mean (unadjusted)	Least Squares Mean (adjusted)
1 Area Commander	10	0.237	$\boxed{606.0}$	606.0
4 Breathing Zone Commander	10	0.237	561.0	561.0
6 Breathing Zone Loader	10	0.237	406.0	406.0
3 Area Loader	10	0.237	294.0	294.0
2 Area Driver	8	0.234	236.3	236.2
5 Breathing Zone Driver	10	0.237	$\boxed{217.0}$	217.0

Treatment comparisons using least squares means (adjusted for amount of firing), alpha = 0.010 per comparison.

Since means and least squares means are virtually the same, use Tukey-Kramer.

Treatment comparisons using Tukey-Kramer multiple comparisons test, alpha = 0.05 for experimentwise error rate.

Area commander significantly higher than breathing zone driver.

Legend: Means within solid boxes are statistically alike. Dashed boxes denote means different only from means in other dashed boxes.

TABLE 43

FORT CARSON AND FORT KNOX M60 PEAK CO CONCENTRATIONS (ppm)

Breathing zone gunner, commander, and loader are significantly higher than area driver concentrations

Treatment	No. of Vehicles	Mass Min	Mean (unadjusted)	Least Squares Mean (adjusted)
6 Breathing Zone Loader	10	1.450	1401.0	1353.8
7 Breathing zone gunner	11	1.630	1230.0	1220.5
4 Breathing Zone Commander	11	1.800	1065.5	1091.4
3 Area Loader	14	1.678	904.3	904.7
5 Breathing Zone Driver	11	1.796	779.1	804.1
1 Area Commander	14	1.678	792.1	792.5
2 Area Driver	14	1.678	387.1	387.5

Treatment comparisons using least squares means (adjusted for amount of firing), alpha = 0.010 per comparison.

Breathing zone loader, gunner, and commander significantly higher than area driver.

Treatment comparisons using Tukey-Kramer multiple comparisons test, alpha = 0.05 for experimentwise error rate.

Breathing zone loader and gunner significantly higher than area driver.

Legend: Means within solid boxes are statistically alike. Dashed boxes denote means different only from means in other dashed boxes.

TABLE 44

M109 ORGANIC COMPOUNDS WITH SIGNIFICANTLY DIFFERENT CONCENTRATIONS (ug/m^3)

Treatment	No. of Vehicles	Total Mass	NON Mean (unadjusted)	NON Least Squares Mean (adjusted)	IND Mean (unadjusted)	IND Least Squares Mean (adjusted)	TMN Mean (unadjusted)	TMN Least Squares Mean (adjusted)
3 Area Loader	10	147.600	26.240	26.644	58.000	57.568	38.900	38.727
2 Area Driver	8	142.500	20.265	21.376	52.800	51.610	23.762	23.287
1 Area Commander	10	156.000	7.400	6.638	19.453	20.269	8.973	9.299
4 Breathing Zone Commander	9	148.000	6.433	6.781	11.702	11.329	1.508	1.359
5 Breathing Zone Driver	12	152.000	6.141	5.935	8.232	8.453	4.121	4.209
6 Breathing Zone Loader	10	154.800	5.654	5.058	9.160	9.798	3.212	3.467
Treatment comparisons using least squares or Tukey-Kramer lead to same conclusions.			Area loader significantly higher than all others except area driver.		Area loader significantly higher than all others except area driver. Area driver different from all breathing zone positions.		Area loader significantly higher than all others except area driver. Area driver different from all breathing zone positions.	

Legend: Means within solid boxes are statistically alike. Dashed boxes denote means different only from means in other dashed boxes.

TABLE 45

M60 ORGANIC COMPOUNDS WITH SIGNIFICANTLY DIFFERENT CONCENTRATIONS (ug/m^3)

Treatment	No. of Vehicles	Total Mass	DMBZ Mean (unadjusted)	DMBZ Least Squares Mean (adjusted)	MNAP Mean (unadjusted)	MNAP Least Squares Mean (adjusted)
5 Breathing Zone Driver	7	74.571	393.514	364.695	150.143	140.286
7 Breathing Zone Gunner	6	75.425	278.667	252.146	109.333	100.262
6 Breathing Zone Loader	5	95.926	175.560	204.245	46.160	55.971
3 Area Loader	5	101.626	140.196	184.230	65.220	80.281
1 Area Commander	6	90.638	157.917	172.363	75.833	80.774
4 Breathing Zone Commander	3	56.450	237.000	159.383	83.333	56.786
2 Area Driver	5	95.926	56.200	84.885	37.040	46.851

Treatment comparisons using least squares means (adjusted for amount of firing), alpha = 0.010 per comparison.

Breathing zone driver significantly higher than area driver.

Breathing zone driver significantly higher than breathing zone loader, breathing zone commander, and area driver.

Since means and least square means noticeably different, Tukey-Kramer multiple comparisons not used.

Legend: Dashed boxes denote means different only from means in other dashed boxes.

3.3.5.3 Metals

Only the Fort Benning M3 exhibited any treatment differences. These differences for aluminum, magnesium, and titanium are presented in Table 46 and show the area/loader concentration to be significantly higher than various others including the area/commander concentration.

3.3.5.4 Other Compounds

On the basis of simple descriptive statistics (mean and standard deviation), statistically significant differences among treatments cannot be identified although they may exist as noted previously.

3.3.6 Differences between General Area Samples and Breathing Zone Samples

3.3.6.1 Issues

The issue of general area vs breathing zone monitoring has been addressed indirectly in the analysis of treatment comparisons. In this analysis, each treatment is a combination of crew position and type of sample, e.g., general area/commander. Where there are large differences (or close similarities) between general area samples and breathing zone samples, statistical groupings of dissimilar (similar) treatment concentrations would be expected generally to fall along these lines. For example, area/commander samples would be statistically different from (similar to) breathing zone/commander samples. Nothing so obvious is apparent across all vehicle types and analytes.

The issue of general area vs breathing zone monitoring seems to be in part one of understanding what one wishes to characterize. Where short-term exposure is a possible concern, localized variability of concentration within a vehicle may be important. In comparing a fixed general area sample against a mobile breathing zone sample, then, the question is whether or not area samples and breathing zone samples experience the same concentrations, i.e., are there local variations experienced by the soldiers large enough to make area samples unrepresentative of soldier exposure.

Of course, in addition to localized concentrations, the movement of the soldiers will affect their exposure, especially exiting from the vehicle. Exiting from the vehicle was limited by keeping the breathing zone sampling vests inside the vehicle as much as possible. For example, as new troops replaced old troops in the vehicle, the vests stayed with the vehicle and were passed to the new troops. When troops did leave the vehicle while wearing the vest, the exit time was controlled.

TABLE 46

M3 METALS WITH SIGNIFICANTLY DIFFERENT CONCENTRATIONS (ug/m^3)

Treatment	No. of Vehicles	Total Mass	Al Mean	Al Least Squares Mean	Mg Mean	Mg Least Squares Mean	Ti Mean	Ti Least Squares Mean
3 Area Loader	5	10.3420	278.4	279.3	82.2	82.5	23.0	23.0
5 Breathing Zone Driver	4	9.8400	114.1	124.1	25.3	28.5	8.7	9.5
2 Area Driver	5	10.3420	96.2	97.1	19.6	19.9	6.1	6.2
6 Breathing Zone Loader	5	10.3420	74.4	75.2	22.1	22.3	7.4	7.4
1 Area Commander	5	10.3420	66.3	67.2	14.8	15.0	5.7	5.8
4 Breathing Zone Commander	3	11.4267	81.3	62.4	28.0	21.9	7.7	6.1
Treatment comparisons using least squares means (adjusted for amount of firing), alpha = 0.010 per comparison.			Area loader significantly higher than breathing zone loader, breathing zone commander, and area commander.		Area loader significantly higher than area driver and area commander.		Area loader significantly higher than area driver, area commander, and breathing zone loader.	
Tukey comparisons using Tukey-Kramer multiple comparisons test, alpha = 0.05 for experimentwise error rate.			Area loader significantly higher than area commander.		No differences		Area loader significantly higher than area driver and area commander.	

Legend: Dashed boxes denote means different only from means in other dashed boxes.

3.3.6.2 Comparisons

In addition to treatment comparisons, further analyses comparing general area and breathing zone samples were conducted using CO data. Peak CO concentrations are integrated over shorter time intervals than other analytes and may more easily reflect localized variations. Also, CO may present short-term exposure risks. The same analyses were also conducted using average CO.

CO data were selected to include only pairs of data, where both breathing zone and general area samples for corresponding positions were gathered under the same conditions (same fort, same vehicle type, same individual vehicle, same day). For each pair, the general area concentration was subtracted from the breathing zone concentration forming a data set of differences in concentration between breathing zone and general area samples. If the two types of sampling are comparable, the differences, on average, should be near zero.

This hypothesis was tested statistically (paired t-test) for each treatment for vehicles at all six forts. Despite the small number of pairs of data for such an analysis, statistical differences were seen as described in Table 47. No meaningful comparison could be done for the Fort Carson M109 since there were only four data points in total.

For the Fort Benning M3 and the Fort Sill M109 significant differences between area and breathing zone samples were seen for average CO in the commander position. For the Fort Knox M1, differences were detected for average CO loader, peak CO loader, and marginally ($p=0.06$) for peak CO driver. Average CO differences were also significant for the Fort Knox M60 driver. Peak CO differences were marginally significant ($p=0.09$) for the Fort Sill M109 loader. When data are combined for each fort across crew positions, differences between general area and breathing zone data are significant for the Knox M1 (both average and peak CO) and the Knox M60 (peak and marginally at $p=0.07$, average CO). The loss of significant differences in the Fort Sill M109 and the Fort Benning M3 when crew positions are combined could be indicative of the effect of soldier movements, or in other words, the uniqueness of each breathing zone/general area pairing.

Apart from displaying statistically significant means of differences, Table 47 also shows some characteristics of the data of practical importance. The magnitude of disagreement between area and breathing zone samples is large on average for peak CO concentrations especially in the tanks, where it ranges from 216 to 585 ppm. The variability of this difference is large, which explains statistically why differences of even large magnitude may not be significant.

TABLE 47

DIFFERENCES BETWEEN BREATHING ZONE AND AREA SAMPLES FOR CO (ppm)

Breathing zone and area samples were statistically different for some treatments

Fort	Position	N (no. of differences)	Peak CO (ppm) Mean of[1] differences	Peak CO (ppm) Standard deviation (variability)	Average CO (ppm) Mean of[1] differences	Average CO (ppm) Standard deviation (variability)
Fort Benning M3	commander	10	-45.0	289.9	-1.7*	2.3
	driver	8	-26.2	108.9	2.2	4.6
	loader	10	112.0	354.0	-0.3	3.0
	combined	28	16.4	279.6	-0.1	3.6
Fort Sill M109	commander	17	-117.1	447.9	-1.9*	3.6
	driver	12	-185.8	375.1	1.1	3.6
	loader	14	245.0**	503.1	1.7	4.8
	combined	43	-18.4	476.1	-0.5	4.2
Fort Carson M60	commander	8	-178.75	885.2	-22.2	43.6
	driver	8	543.7	932.1	-3.9	17.9
	loader	6	306.7	650.4	4.7	11.1
	combined	22	216.4	868.4	-8.2	30.0
Fort Knox M60	commander	3	1156.7	996.2	0.0	10.0
	driver	3	116.7	204.0	16.7*	5.8
	loader	4	507.5	889.7	22.5	32.0
	combined	10	585.0*	823.6	14.0**	21.7
Fort Knox M1	commander	3	-90.0	215.2	-3.3	15.3
	driver	5	142.0**	120.3	8.0	13.0
	loader	7	404.3*	290.3	24.1*	25.6
	combined	15	218.0*	294.3	13.3*	22.1

*Statistically significant from zero at alpha = 0.05.
**Marginally significant (significant at alpha = 0.10).

[1] Means are the mean of breathing zone minus area sample data for corresponding crew position pairs. If the two samples are equivalent, differences should average near zero.

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4.0 CONCLUSIONS

Three major issues were addressed in this experimental program. First, the character and magnitude of weapons' combustion products in armored vehicles was determined. Secondly, the variation in potential exposure to these pollutants across selected armored vehicles and within these vehicles was evaluated. Thirdly, the efficacy of monitoring in such a rigorous environment was assessed. On the basis of field monitoring, experimental analysis, and statistical comparison several observations can be made with respect to each area of concern.

4.1 WEAPONS' COMBUSTION PRODUCTS

The characterization of the air in armored vehicles during firing exercises was facilitated by the use of sampling and analysis methods which were optimized to permit the collection of large sample volumes and thus enhance the ability to identify and quantify trace pollutants. Several inorganic compounds and some members of each class of compounds identified in the following table were found in one or more armored vehicles during firing scenarios typical of those conducted at U.S. Army Training and Doctrine Command or U.S. Army Forces Command installations.

TABLE 48. WEAPON POLLUTANTS

Carbon Monoxide	Vapor Phase Organics (Hydrocarbons)
Ammonia	Aldehydes
Carbon Dioxide	Polycyclic Aromatic Hydrocarbons (PAHs)
Hydrogen Cyanide	Nitro-PAHs
Hydrogen Sulfide	Particulates (Total, Respirable)
Nitrogen Oxides	Metals
Sulfur Dioxide	

The concentrations of individual compounds found in all vehicles represent time-weighted averages observed during the firing exercises, except for carbon monoxide which was also monitored in real time (10-second intervals). Observations concerning the magnitude of pollutant concentrations are:

(1) On several occasions, carbon monoxide averaged over 400 ppm for 15-minute periods in tanks. On one occasion, the CO reading remained above 1500 ppm for almost 40 minutes; the NRC Emergency and Continuous Exposure Limit is 1500 ppm for 10 minutes. (However, this high reading was not confirmed by other CO monitors in the vehicle at the time and may be anomalous.)

(2) Carbon monoxide was observed to exceed 2000 ppm for shorter periods in all vehicles except the Bradley Fighting Vehicle, where the peak level was 1300 ppm.

(3) Mean carbon monoxide concentrations ranged from 3.6 to 4.7 ppm in the non-tank vehicles (M3 and M109) and from 35 to 43 ppm in the tanks.

(4) With few exceptions, the maximum concentrations of all other pollutants in all vehicles were less than their respective threshold limit values and far below emergency exposure limits.

(5) The mean concentrations of pollutants other than CO were generally a fraction (one half to one tenth) of the threshold limit values. With the exception of carbon monoxide and carbon dioxide, most pollutants were observed at concentrations ranging from tens to hundreds of $\mu g/m^3$.

(6) In many cases, the pollutant concentrations in the non-tank vehicles were noted to be below the analytical detection limit.

4.2 COMPARISON OF VEHICLE CONCENTRATIONS

The magnitude of pollutant concentrations was observed to vary significantly across vehicle types and, in some cases, within vehicles. Thus, the exposure received by crew members of armored vehicles may vary significantly. It was observed that:

(1) The peak instantaneous concentrations of pollutants generated during weapon firing, and to which crewmen such as the ammunition loader are exposed, may exceed 500 times the average concentrations inside vehicles. These peak excursions are very localized and short-lived.

(2) Carbon monoxide, which is a major combustion product, is observed at statistically significantly higher mean and peak concentrations in tanks (M1; M60) compared to non-tank vehicles (M3; M109).

(3) All other pollutants are generally observed at higher levels in tanks than non-tank vehicles, although the statistical significance of this observation is effected by sample size and variability.

(4) Some compartmentalization of pollutant concentration is apparent in armored vehicles. The concentration of carbon monoxide in the forward control (driver) area is generally significantly lower than that in the weapon handling (loader, gunner) or command/observation (commander) areas. This is consistent with the segregation of the driver's area from the rest of the vehicle.

(5) Differences in general area and breathing zone samples were observed to be significant in the tanks (M1 and M60) for peak and average CO concentrations. Some differences in general area and breathing zone samples were observed for the non-tanks (M3 and M109) at selected positions.

4.3 MONITORING OF ARMORED VEHICLES

The rigor and complexity of field sampling in armored vehicles during firing exercises can be successfully dealt with if proper planning and careful limitation of the duration of sampling is followed. The most significant observations made during this study are:

(1) Portable monitoring equipment can be safely and unobtrusively deployed in armored vehicles including those with limited space, i.e., tanks, by utilizing small boxes and/or storage areas which are frequently empty during training exercises.

(2) By careful packaging of the equipment, such as wrapping in bubble wrap or taping of switches, field monitors are found to operate for up to four hours without failure.

(3) The use of sampling vests for breathing zone measurements is feasible although subject to failure due to the activity of the subject.

(4) Operation of equipment beyond four hours or in darkness increases the incidence of failure. This is especially true for breathing zone sampling.

(5) Monitoring can be conducted with minor but acceptable interference to the field command except during night-time operations.

(6) Sampling methods utilizing filters and sorbent tubes are sufficiently rugged for use in the vehicles. It is even feasible to perform general area sampling with impingers.

(7) There is a practical limit to sampling rates and periods for each pollutant but this limit does not preclude attainment of a level of sensitivity equivalent to a fraction of typical threshold limit values.

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5.0 LITERATURE CITED

1. Snelson, A., P. Ase, W. Bock and R. Butler. 1983. Characterization of Combustion Products of Military Propellants. Volumes I and II. IIT Research Institute, Chicago, IL. DAMD17-80-C-0019.

2. Ase, P., W. Wisenberg, S. Gordon, K. Taylor and A. Snelson. 1985. Propellant combustion product analyses on an M16 rifle and an M105 MM caliber gun. Environ. Sci. Health A20(3):337-368.

3. U.S. Army Environmental Hygiene Agency. 1984. Industrial Hygiene Study No. 55-35-0137-84. Determination of the Composition of Combustion Products During Tracer Firing, Lake City AAP, Independence, MO. 20 November - 2 December 1983.

4. NIOSH. 1977. Manual of Analytical Methods, 2d Edition. U.S. Department of Health, Education and Welfare, Publ. (NIOSH) 77-157-C.

5. NIOSH. 1984. Manual of Analytical Methods, 3d Edition. U.S. Department of Health, and Human Services, Publ. (NIOSH) 84-100.

6. McCammon, C.S., Jr. 1979. Advances in personal gas and vapor monitoring. J. Environ. Pathol. Toxicol. 2(5):325-34.

7. Ramsey, R.S., R.A. Jenkins and W.H. Griest. 1985. Unpublished Draft. Problem Definition Study on Techniques and Methodologies for Evaluating the Chemical and Toxicological Properties of the Combustion Products of Rifle and Gun Systems. Section IV: Review and Analysis of Analytical and Industrial Hygiene Sampling Techniques Utilized to Evaluate the Chemical Composition of Combustion Products. Oak Ridge National Laboratory, Oak Ridge, TN.

8. Heitbrink, W.A. and L.J. Doemeny. 1979. A modified impinger for personal sampling. Am. Ind. Hyg. Assoc. J. 40(5):354-64.

9. Williams, F.W., J.P. Stone and H.G. Eaton. 1976. Personal atmospheric gas sampler using the critical orifice concept. Anal. Chem. 48(2):442-5.

10. Pinches, M.A. and R.F. Walker. 1980. Determination of atmospheric contaminants using a continuous paper-tape personal monitor - I. Analysis of aromatic amines. Ann. Occup. Hyg. 23(4):335-52.

11. Segal, A., L. Gordon and S. Sudberg. 1978. A new personal monitoring device for the detection of β-propiolactone and other alkylating agents. Arch. Env. Health 33(1):33-5.

12. Denenberg, B.A., and R. Kriesel. 1976. Chemically impregnated paper tapes as a detection method in continuous personal and area monitors. Am. Ind. Hyg. Assoc. J. 37(4):246-50.

13. Vo-Dinh, T. 1985. Development of a dosimeter for personnel exposure to vapors of polyaromatic pollutants. Environ. Sci. Technol. 19(10):997-1003.

14. Montalvo, J., Jr. 1979. Total elemental content passive personal monitors. Am. Ind. Hyg. Assoc. J. 40(12):1046-54.

15. Gold, A., W.A. Burgess and E.V. Clougherty. 1978. Exposure of firefighters to toxic air contaminants. Am. Ind. Hyg. Assoc. J. 39(7):534-9.

16. Carter, K.B., and M.M. Halliday. 1978. A personal air sampling pump for hospital operating staff. J. Med. Eng. Tech. 2(6):310-2.

17. Hill, R.H., H.G. Enoch, M.A. Hannan and L. Recro. 1980. Worker Exposure in a Coal Liquefaction Facility Determined by Industrial Hygiene air Monitoring and Urine Mutagenicity Testing.

18. Akland, G.G., T.D. Hartwell, T.R. Johnson and R.W. Whitmore. 1985. Measuring human exposure to carbon monoxide in Washington, DC, and Denver, CO, during the winter of 1982-1983. Environ. Sci. Technol. 19(10):911-18.

19. Ott, W.R. 1985. Total human exposure. Environ. Sci. Technol. 19(10):880-86.

20. Zweidinger, R., M. Erickson, S. Cooper, D. Whittaker and E. Pellizzari. 1982. Direct Measurement of Volatile Organic Compounds in Breathing-Zone Air, Drinking Water, Breath, Blood, and Urine. U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-600/4-82-015.

21. Menzies, K.T., C.M. Wong, L.C. Magni and M.A. Randel. 1985. Development of a routine technique for analysis of nitro-PAH in diesel particulate extract. Final Report. Coordinating Research Council, Inc., Atlanta, GA.

22. Adams, J.W., et al. April 1977. Selection and Evaluation of Sorbent Resins for the Collection of Organic Compounds. Final Report. U.S. Environmental Protection Agency, Contract No. 68-02-1332.

23. Menzies, K.T., et al. February 1985. Development of a Routine Technique for Analysis of Nitro-PAH in Diesel Particulate Extract. Final Report. Coordinating Research Council, Inc., Contract No. CAPE-30-81.